Barataria-Terrebonne Estuary System Climate Change Adaptation Plan 2020

BTNEP
BARATARIA-TERREBONNE NATIONAL ESTUARY PROGRAM

Estuary Issues
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THE BARATARIA-TERREBONNE ESTUARY SYSTEM CLIMATE CHANGE ADAPTATION PLAN 2020 IS RESEARCH PREPARED FOR THE BARATARIA-TERREBONNE NATIONAL ESTUARY PROGRAM BY:

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Image: The Water Institute of the Gulf

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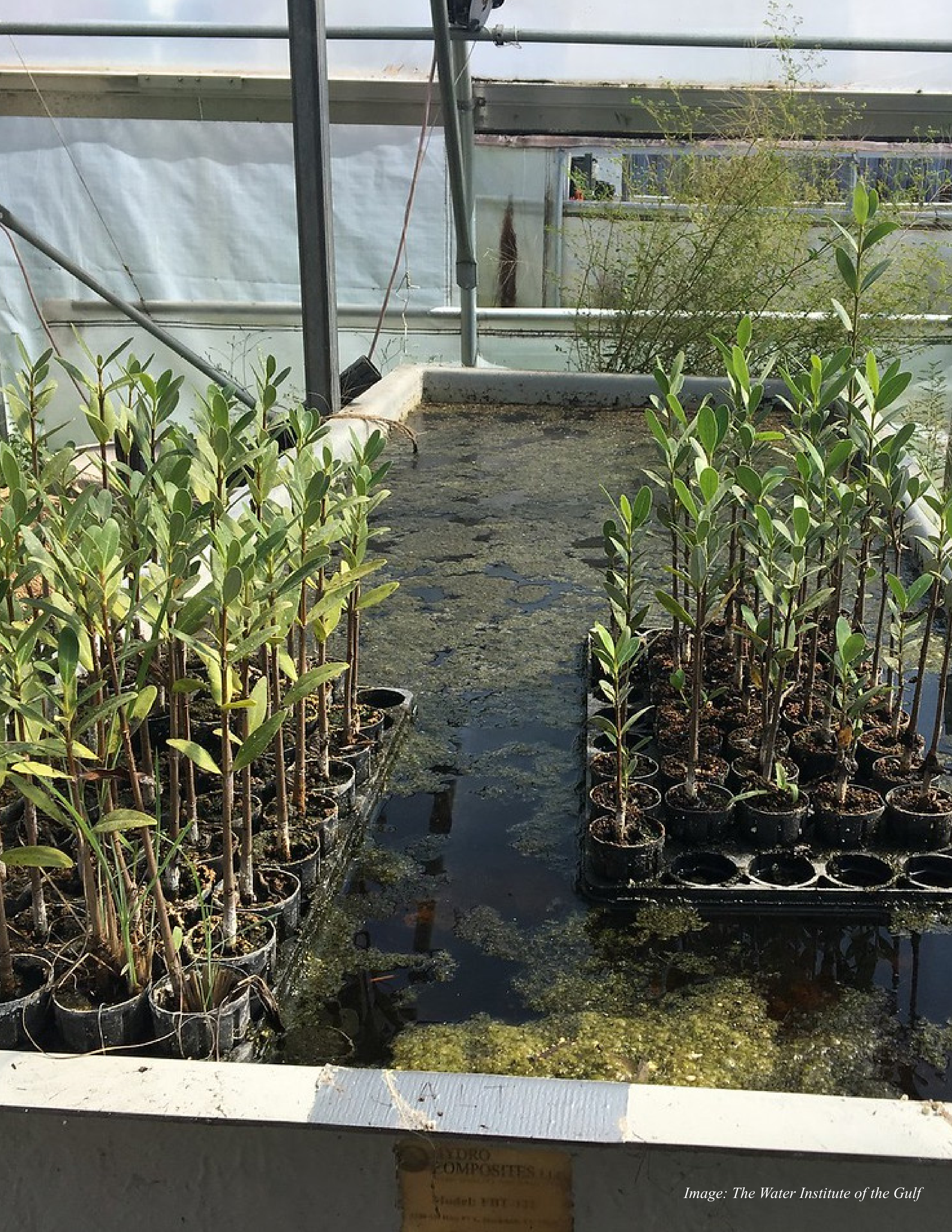

Image: The Water Institute of the Gulf

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INTRODUCTION

Preparing for Climate Change in the Barataria-Terrebonne National Estuary

Coastal Louisiana is a naturally dynamic environment that has undergone many changes over the last several thousand years from movements of the mouth of the Mississippi River and a series of shifting river deltas. In recent decades, globally high rates of land loss and a rapid transition of habitat types have resulted from of a number of natural and anthropogenic factors. The Barataria-Terrebonne Estuary System (BTES), the 4.2 million-acre region between the Atchafalaya and Mississppi Rivers. is at the heart of these changes. From 1932 to 2010 the Barataria and Terrebonne Basins lost over 290,000 and 320,000 acres of land, respectively (Couvillion et al., 2011). As a result, the BTES has experienced several cascading effects including changes in local vegetation patterns, shifting wildlife habitat, and a loss of protective buffers that shield the area from saltwater intrusion, tropical storms, high tide flooding, and damaging winds.

While the BTES is experiencing basin-wide outcomes of climate change, many impacts of land loss are experienced at a more local, site-specific scale. In the last decade, Lake Boudreaux in Terrebonne Parish, for example. experienced shoreline erosion rates ranging as high as 15 to 25 meters per year (49 to 82 feet per year). Interior ponding, and a conversion of habitat from marsh to open water, is occurring in many of the fresh flotant marshes found in the northern reaches of the BTES. In the southern reaches of the estuary that are in close proximity to the Gulf of Mexico, the magnitude of erosion and loss of saline marshes exceeds those along interior water bodies surrounded by brackish, intermediate, or fresh marshes (Barras et al., 2003; Morton & Barras, 2011). While many of these impacts are in large part the result of continuing subsidence combined with rising sea levels, the impacts of landscape-scale anthropogenic alterations cannot be understated. The construction of levees and other structural protection features along the Mississippi River and its tributaries have resulted in a reduced replenishment of sediment into wetland floodplains, hastening the rate of wetland loss (Twilley et al., 2016). Subsidence has been caused both by the natural densification of sediment over time and the industrial extraction of oil (Kolker et al., 2011).

Coastal land loss, despite the best efforts of scientists, planners, and residents, is expected to continue. According to the State of Louisiana, if no action is taken, as much as 4,123 square miles of land could be lost within the next 50 years, in addition to the nearly 1,900 square miles of land area lost between 1932 and 2010 (Coastal Protection and Restoration Authority of Louisiana, 2017). The greatest potential impacts of future land loss in coastal Louisiana occur in locations where physical vulnerability coincides with concentrations of population, infrastructure, and natural resources, including fisheries. Communities located within the BTES are extremely vulnerable to future hazards events due to a combination of high local rates of relative sea-level rise, significant shoreline erosion and wave energy, and concentration of economically valuable infrastructure (Hemmerling, 2017). The estuary also provides vital habitat for commercial and recreational fisheries and many threatened

or endangered shorebirds.

Climate change will only exacerbate these changes. The warming climate will lead to more severe floods, droughts, and sea level rise, in addition to ocean acidification from algal blooms and increased carbon dioxide in the air. These changes may result in damage to the built environment and alterations to the natural environment, posing a particular risk to natural resource dependent industries such as agriculture, seafood, and oil and gas. The sea level rise that will be induced by climate change will accelerate the coastal erosion and land loss that has already been occurring in the BTES region. With a higher sea level, the ability for levees to protect coastal areas from flooding will be reduced. Railways, airports, and oil and gas facilities that are near the coast will be susceptible to more damage from flooding. Many of the southernmost communities in the BTES are gradually becoming uninhabitable, causing statewide conversations about residential relocation.

THE BARATARIA-TERRERBONNE NATIONAL ESTUARY PROGRAM

The National Estuary Program was established by Congress through Section 320 of the Clean Water Act of 1987. The BTES became a National Estuary in 1990 and the Barataria-Terrebonne National Estuary Program (BTNEP) was established shortly thereafter. As one of 28 National Estuary Programs in the United States and its territories, BTNEP is tasked with protecting and preserving the land, water, people, and culture of the BTES. Also in 1990, the BTNEP Management Conference (BTNEP MC) was created. The Management Conference consists of diverse stakeholders who collaborate to address the preservation and restoration of the estuary through a science-based, collaborative decision-making process while addressing and supporting stakeholder interests. The mission of BTNEP is to rebuild and protect the estuary for future generations. Through the collaborative decision making process of the BTNEP MC, BTNEP implements a science-based, stakeholder-led, consensus-driven plan using partnerships focused on the estuary's rich cultural, economic, and natural resources.

DEVELOPING A RISK-BASED ADAPTATION PLAN

The following report summarizes BTNEP's efforts to develop a plan for adapting to the anticipated effects of climate change in coastal Louisiana. To accomplish this goal, BTNEP has partnered with the Water Institute of the Gulf (the Water Institute) to undertake a strategic process described in the U.S. EPA's *Being Prepared for Climate Change: A Workbook for Developing Risk-based Adaptation Plans* (the Workbook). The Workbook is part of a pilot project designed by the Climate Ready Estuaries program under the EPA's National Estuaries Program (U.S. Environmental Protection Agency, 2014). The Workbook is a tool intended to help National Estuary Programs such as BTNEP identify a suite of risks associated with climate change, carry out vulnerability studies, and develop a plan for adapting to the impacts caused by climate change (Bauzá-Ortega, 2015). The EPA provides a step-by-step methodology built upon a series of participatory and interactive processes that bring together local and regional expertise, including both local and technical knowledge experts.

This report draws upon the expertise of the BTNEP Management Conference, a diverse group of local stakeholders including representatives from

"Aerial view of Larose-Golden Meadow, Louisiana, looking south to the Gulf of Mexico. Degradation of the marsh due to canals and subsidence is evident." Image: Coastal Protection and Restoration Authority and Barataria-Terrebonne National Estuary Program, 2018

industry and business, fisheries, agriculture, oil and gas, government agencies, individual citizens, landowners, civic organizations, hunters, scientists, engineers, environmentalists, economists, and urban planners. The strategic process in this report includes two parts: (1) An analysis of the vulnerability of the Barataria-Terrebonne estuarine system, and (2) a plan of action to mitigate and address the most locally pertinent climate change risks. This report consists of four chapters that outline the background information for the strategic process (Chapters 1, 2, and 3) and the results of the strategic process itself (Chapter 4). The first chapter provides detailed background information on the people and resources in the Barataria Terrebonne national estuary. The second chapter outlines the impacts that climate change is having on the estuary. The third chapter explains how the Workbook was used to develop the BTNEP climate adaptation plan while the fourth and final chapter details the results of BTNEP's vulnerability assessment and adaptation plan.


Image: The Water Institute of the Gulf

CHAPTER 1

The Barataria-Terrebonne Estuary System: People, Resources, and Economies

The BTES was built gradually over thousands of years by sediment deposition from the Mississippi River and is one of the youngest geological areas in the United States (Fisk & McFarlan, 1955; Roberts, 1997). The Estuary sits within the fourth largest drainage basin in the world, located between the Mississippi and Atchafalaya rivers (Blum & Roberts, 2012). The Mississippi-Atchafalaya River drainage basin covers 31 states and two Canadian provinces (Blum & Roberts, 2012; Rittenour et al., 2007).

The BTES is 4.2 million acres in size, consisting of the Barataria (1.7 million acres) and Terrebonne (2.5 million acres) Basins (Couvillion et al., 2011). The two basins, Barataria and Terrebonne, are separated by Bayou Lafourche, which runs north to south. There are a variety of habitats in the system including agricultural lands, forests, swamps, marshes, levees, islands, bays, bayous, ridges, and other habitats.

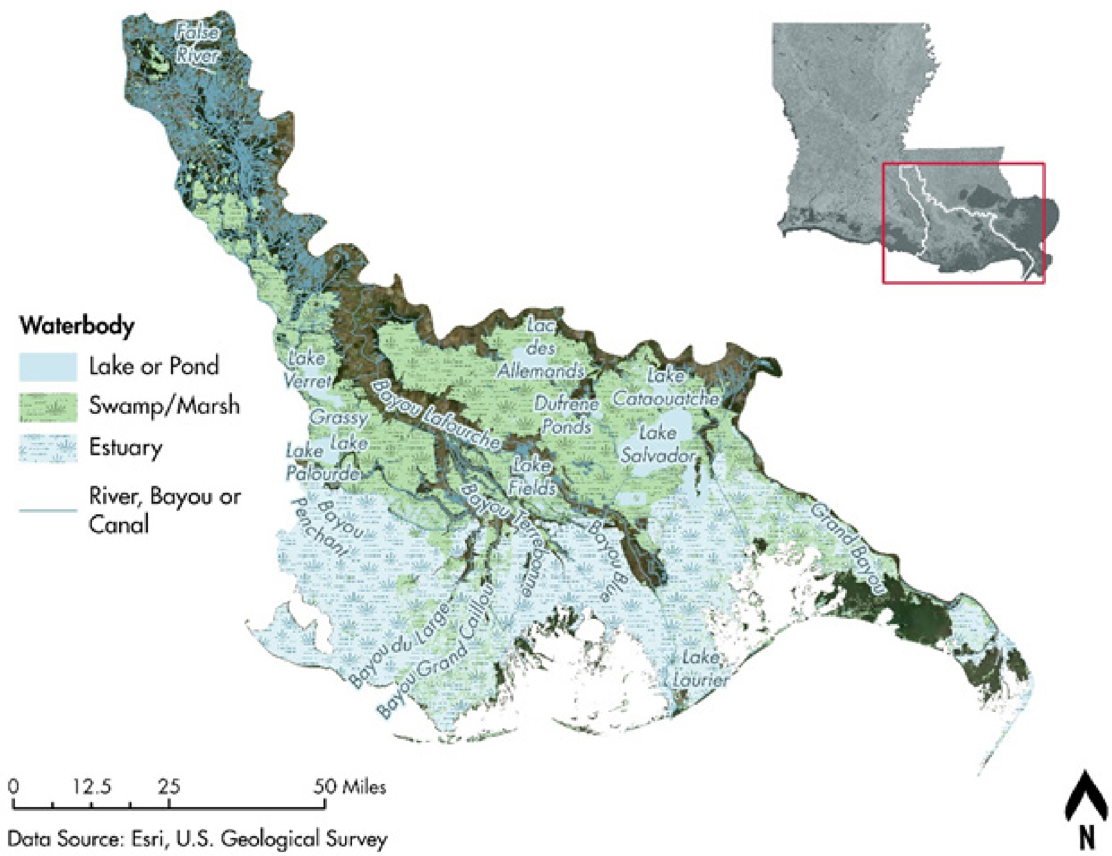


Figure 1. Waterbodies in the BTES

The Landscape

RIDGES AND UPLAND FORESTS

Natural ridges are areas of higher elevation, usually along old river or bayou paths, that influence the water flow dynamics of an area (CPRA, 2017). Ridges provide flood protection, wave and storm attenuation, and locations for residents to build their homes. High ridges along bayous can provide habitat for the larger trees of upland forests, such as oaks, elm, and sweetgum. Older upland forest ecosystems have a well-defined tree canopy, sub-canopy, and shrub layers. There is heavy shading of the lower layers by the larger trees resulting in a lot of shade-tolerant species. The upland forests of the BTES are receding as they have been cleared for agriculture and urban development due to its higher elevation and reduced susceptibility to flooding. The upland forest that remains tends to be in older and lower elevation areas that were too small to be developed. These habitats provide protection to a range of mammals, birds, and reptiles – such as deer, rabbits, armadillos, turkey, quail, migratory songbirds, and alligators (Barataria-Terrebonne National Estuary Program, 2018).

LEVEES

Levees range in size and origin. Low natural levees occur along many rivers and bayous, while larger levees have usually been constructed on top of natural levees (O'Neil, 1949). Levees play a crucial role in protecting populations from storm surge and flooding (CPRA, 2017). Natural levees constrain

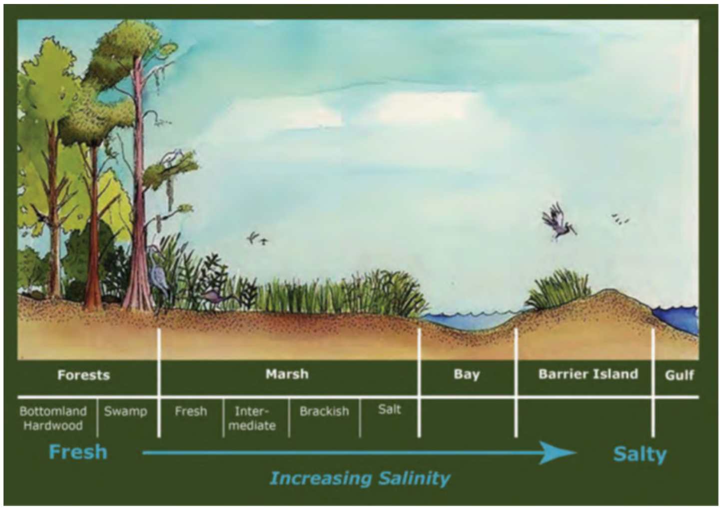


Figure 2. Diverse habitats within the BTES. Source: (Barataria-Terrebonne National Estuary Program, 2018).

flowing water at low levels and allow water to overflow (and potentially change course) in times of high flow (O'Neil, 1949). Conversely, man-made levees along the Mississippi River (and other tributaries to the BTES) have contributed to land loss by preventing natural and historic river flooding processes, which prevents river sediment from nourishing the marshes (Barry, 1998; Couvillion et al., 2017b).

BAYOUS

Bayous support freshwater habitats for a wide range of plants and animals and provide recreational benefits to people. Most of the bayous within BTES are outside of tidal influence, but some of the southern bayous are impacted both by tide and saltwater intrusion (CPRA, 2017). Largemouth bass (Micropterus salmoides) is a popular sportfish in BTES lakes because they can tolerate brackish water although they prefer to nest along quiet

Levees provide flood risk reduction measures for property, population centers, and ecosystems. Image: U.S. Army Corps of Engineers and Barataria-Terrebonne National Estuary Program, 2018

freshwater lake and bayou shorelines. Freshwater catfish (Ictalurus spp.) is a popular recreational and commercial fish species found in similar environments.

BOTTOMLAND HARDWOOD FORESTS

Bottomland hardwood forest habitat has the highest diversity in number of tree and shrub species in the BTES and is mostly found in the northern region, east of the Atchafalaya River. These forests are defined by alternating wet and dry periods due to typically seasonal variations in riverine flood stage. The prevalence of this habitat has decreased over time as floodway engineering has disconnected many of these forests from the river. This habitat serves as a popular nesting ground for bald eagles and migratory birds and provide forage for deer, squirrel, and wood duck. Louisiana black bear can

Alligator in Bayou Terrebonne. Image: The Water Institute of the Gulf

Cypress swamp. Image: The Water Institute of the Gulf

also be found here (Barataria-Terrebonne National Estuary Program, 2018).

CYPRESS-TUPELO SWAMPS

In the BTES, swamps are freshwater forested wetlands. Bald cypress and tupelo gum trees stand with buttress trunks on ground that is covered with water throughout the trees' growing season. These areas are only found dry during times of extreme drought. Cypress-Tupelo swamps are found further south than bottomland forests and surround large lakes and bayous. These swamps help filter rainwater runoff by removing pollutants and debris. They are most commonly found in the Barataria Basin around Lac des Allemands and Bayou Boeuf and may be found with flood-tolerant trees such as swamp red maple, black willow, water elm, and buttonbush (Barataria-Terrebonne National Estuary Program, 2018).

A variety of species call the swamp home, including gar, crawfish, alligators, cottonmouths, snapping turtles, otters, beavers, and invasive nutria. Swamps are also nesting habitat to herons, ibises, egrets, wood ducks, and predator birds such as the barred owl and the red-tailed hawk (Barataria-Terrebonne National Estuary Program, 2018).

MARSHES

There are four marsh type (or salinity zone) classifications found in the BTES: fresh (~170,000 acres), intermediate (~60,000 acres), brackish (~100,000 acres), and saline (~130,000 acres) (Chabreck, 1970; Penfound & Hathaway, 1938; The Barataria Basin, n.d.; Visser et al., 1998). The two basins have a similar array of marsh types, but the Barataria Basin has a higher proportion of brackish marsh and a lower proportions of fresh and saline marsh areas than the Terrebonne Basin (Visser et al., 1998). Marshes in the BTES provide habitat to a wide range of invertebrates, fish, shellfish, birds and mammals for their protection and food sources (Pattillo et al., 1997; Stanley & Sellers, 1986).

Marsh wetlands. Image: The Water Institute of the Gulf

Salinity levels in fresh marshes range from 0 to 3 parts per thousand (ppt), which allows them to have the largest plant diversity compared to other marsh types. Prominent plant species in southern Louisiana fresh marshes include maidencane, spike sedge, bulltongue, alligator weed, giant cutgrass, pickerelweed, pennywort, cattail, southern wildrice, coontail, common duckweed, water lilies, irises, and bullwhip (Chabreck, 1970; Penfound & Hathaway, 1938; Visser et al., 1998).

Salinity levels in intermediate marshes range from 2 to 8 ppt and includes vegetation such as wiregrass, widgeongrass, cattails, bulltongue, giant bulrush, common threesquare, deer pea, switch grass, Walter's millet, alligator weed, and southern naiad (Chabreck, 1970; Penfound & Hathaway, 1938; Visser et al., 1998). Alligators tend to rely heavily on this habitat as they primarily nest in marshes with salinities below 10 ppt. BTES is popular with migrating waterfowl species and the mottled duck is the only resident species that prefers fresh to brackish water habitat (Barataria-Terrebonne National Estuary Program, 2018).

Salinity levels in brackish marshes range from 4 to 18 ppt. The dominant vegetation types in brackish marshes is wiregrass. Brackish marshes also include species such as olney bulrush, leafy three square, and widgeon grass (Chabreck, 1970; Penfound & Hathaway, 1938; Visser et al., 1998). The marshes also serve as nurseries for white and brown shrimp before they move back into the Gulf to mature to adulthood (Barataria-Terrebonne National Estuary Program, 2018).

Salinity levels in saline marshes range from 18 to 29 ppt. Saline marshes have a high prevalence of smooth cordgrass (also known as oyster grass) and black mangrove, along with salt grass, black needlerush, and saltwort vegetation (Chabreck, 1970; Penfound & Hathaway, 1938; Visser et al., 1998). Saline marshes are a nursery for larval forms of redfish, speckled trout, menhaden, crabs, and shrimp and fish return as juveniles to shelter, feed,

Shucking oysters fresh from the Louisiana coast. Image: Louisiana Sea Grant and Barataria-Terrebonne National Estuary Program, 2018

and grow. Predatory birds are therefore attracted to this habitat including seaside sparrow, marsh wren, egrets, white ibis, and brown pelican (BTNEP 2016).

BAYS

Bays in the BTES are a transition between the upper estuarine waters and the Gulf of Mexico coastal waters. They range in size and, due to coastal land loss, have increased in size and connectiveness over the years (CPRA, 2017; FitzGerald et al., 2003). Many bays, especially the more southern ones have continued to increase in salinity with saltwater intrusion from coastal erosion and sea level rise (CPRA, 2017). Bays provide important habitat to a range of species, such as brown shrimp, because of the vital nursery grounds in their early life stages. Other species, such as bay anchovy, oyster and spotted sea trout spend most of their life cycles in these habitats (Pattillo et al., 1997; Stanley & Sellers, 1986).

OYSTER REEFS

Oysters are found in reef or bed groupings with habitat preferences of shallow bays, mud-flats, sand bars, and intertidal areas (Hijuelos et al., 2017; Pattillo et al., 1997). Oyster distribution, and subsequent harvests, have fluctuated in the BTES based on annual weather changes (Melancon et al., 1998). In larger numbers, oysters can have a significant impact on filtering organic and inorganic particles allowing for water clarity (Kennedy et al., 1996; Pattillo et al., 1997).

Temperature and salinity are the two of the largest drivers of oyster survival and reproduction; with tidal exposure, availability of food, and turbidity being important considerations as well (Hijuelos et al., 2017; Kennedy et al., 1996). Ideal salinities vary based on life stage and spawning success (Hijuelos et al., 2017), but overall, salinity levels under 8 ppt are highly detrimental especially when water temperatures are warm. If salinity levels are above 15 ppt, there is an increase in predation. Salinities greater than 25 ppt have a negative effect on oyster survivability (Hijuelos et al., 2017; Pattillo et al., 1995). Oyster reefs provide critical habitat to a range of species such as filter feeders (mussels and barnacles). When oysters are adults they are food sources for sheepshead, drilling snails, crabs, and black drum (Pattillo et al., 1997).

BARRIER ISLAND AND HEADLAND BEACHES

Barrier islands are found at the southernmost part of BTES. Barrier islands serve as the first line of defense against storm surge and waves coming toward the Louisiana coast, reducing erosion and flooding to marshes (Wamsley et al., 2009). The barrier islands also serve as a first stop for a

Brown pelicans. Image: The Water Institute of the Gulf migratory birds to rest and eat (CPRA, 2017) and as nesting grounds for species such as brown pelicans (Barataria-Terrebonne National Estuary Program, 2018). Invertebrates and fish species such as anchovies, menhaden, mullet, shrimp, and crabs shelter behind the islands and serve as a food source to birds and mammals on the islands (Pattillo et al., 1997; Stanley & Sellers, 1986).

Historically there was a continuous barrier island, formerly bayou ridges (BTNEP 2016), across these basins with only minimal inlet access (FitzGerald et al., 2003). Headland beaches and barrier islands in BTES have had an extremely high rate of shoreline retreat and erosion both due to their high exposure to storms as well as being sediment starved (Dietz et al., 2018; Ritchie & Penland, 1988). One area of high loss in the BTES is Bay Champagne where roughly 290 meters (950 feet) of shoreline retreat occurred over a 35-year period, which on average is over 8 meters (26 feet) per year (Dietz et al., 2018). The large and increasing rates of retreat impacts critical oil and gas infrastructure near the barrier islands, as well as marshes and communities further inland (Dietz et al., 2018; FitzGerald et al., 2003).

URBAN AND RURAL AREAS

The BTES spans across 16 Louisiana parishes (commonly known as counties elsewhere) which include: Pointe Coupee, West Baton Rouge, Iberville, Iberia, Ascension, Assumption, St. James, St. John the Baptist, St. Martin, St. Charles, St. Mary, Orleans, Terrebonne, Lafourche, Jefferson, and Plaquemines. A substantial portion of the BTES is rural, especially the coastal marshes and farming areas. The largest city in the BTES is Houma (based on population size), which as of the 2010 census had an estimated population of 33,727. Additionally, coastal fishing locations like Venice and Grand Isle are rural, but bring in large numbers of visitors each year.

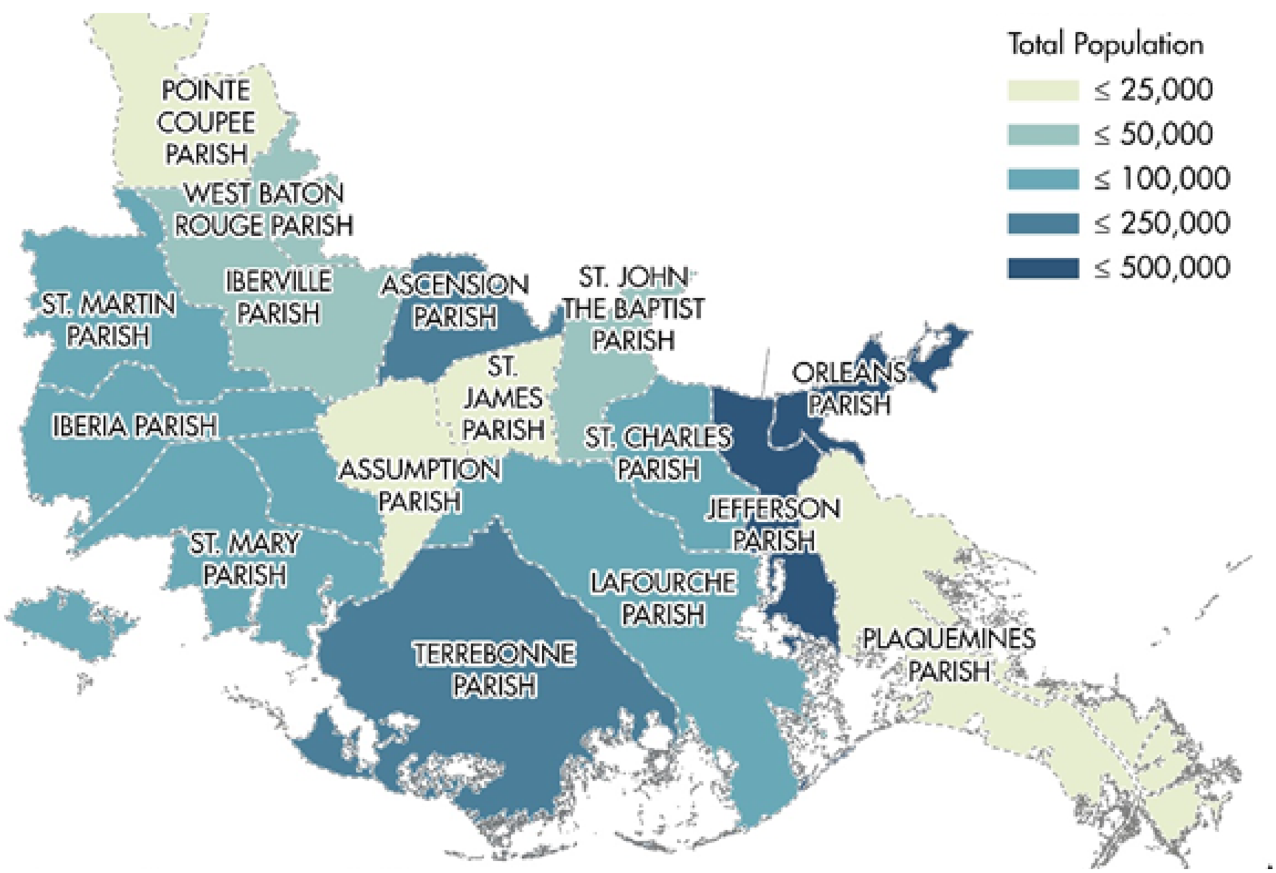


Figure 3. Population Distribution within the Barataria-Terrebonne Estuary System, 2017

Raised homes in Montegut, Louisiana. Image: The Water Institute of the Gulf

Population and Economy

COASTAL ECONOMY

Nearly 34% of all workers in the state of Louisiana reside in coastal parishes – the largest percentage of all five Gulf of Mexico states (Adams et al., 2004). A large portion of this employment centers on coast-specific economy sectors, including: Oil and gas production, commercial and recreational fisheries, marine construction, ship and boat manufacturing, tourism, and marine transportation (Hemmerling et al., 2020; Kildow et al., 2014).

OIL AND GAS

Coastal Louisiana supports nearly one-third of crude oil production and one-fifth of natural gas production in the United States. While the majority of this production occurs offshore in the Gulf of Mexico, processing oil and gas after extraction is an energy-intensive undertaking that requires an expansive network of land-based infrastructure including gas processing plants, refineries, petrochemical plants, and a vast array of pipelines capable of transporting products and intermediates to and from these facilities (Hemmerling et al., 2020; Hemmerling & Colten, 2017).

Over the course of its history in the state, oil and gas development has fostered economic growth and provided employment opportunities for many Louisiana residents. Despite the positive aspects of this development, there are significant hazards posed to wetlands, coastal ecosystems, and communities located adjacent to oil and gas infrastructure (Hemmerling et al., 2020; Lin & Tjeerdema, 2010).

A significant portion of coastal Louisiana's oil and gas infrastructure is located within the spatial extent of the BTES oil and gas production facilities and industries supporting exploration activities (e.g. shipbuilding, platform fabrication, offshore contracting companies) are clustered in coastal communities throughout the watershed, including Golden Meadow, Houma, and Morgan City.

PORTS

Ports in the Barataria-Terrebonne estuary footprint can be categorized as either deep draft, coastal, or inland. The only currently operating deep draft port in the watershed is the Plaquemines Port Harbor and

Raised buildings on Catfish Lake. Image: The Water Institute of the Gulf

Terminal District. Coastal ports in the watershed include Port Fourchon and the ports of Grand Isle, Terrebonne, Morgan City, and Dulac-Chauvin. Krotz springs is the only currently operating inland port located northward in the Atchafalaya Basin (Port Locations, 2019).

FISHERIES

While not employing as many residents as the oil and gas sector, the Louisiana's fisheries sector remains a dominant driver of the state's economy, especially for coastal residents. The state of Louisiana hosts about 1/5th of all commercial fish and shellfish landings in the United States, making it the second largest producer of fisheries behind Alaska (Barataria-Terrebonne National Estuary Program, 2018). Additionally, a significant majority of seafood harvested in the Gulf of Mexico transits through ports in south Louisiana.

Important commercial fish landings in the BTNE include the ports of Dulac-Chauvin and Grand Isle. Finfish comprise most of the commercial landings and include species such as snapper, grouper, tuna, and menhaden (Ogunyinka et al., 2011). The Terrebonne Basin is also an important landing and fisheries location for blue crab fisherman and is a significant contributor to the economy.

Equally important to the local and state economy are the basin's shrimp and oyster fisheries. Shrimp fishermen bottom trawl for three primary Gulf species: white shrimp, brown shrimp, and pink shrimp. Oysters play a significant role in Louisiana culture and oystermen are among the most vocal stakeholders contributing to the coastal land loss discussion (Ogunyinka et al., 2011). Northward in the basin, freshwater fishermen pursue crawfish, alligators, and finfish species such as drum, catfish, and bass (Isaacs, 2018).

AGRICULTURE

There is also a wide spectrum of agricultural practices inside the BTES with the dominant crop being sugar cane. Soybeans, pecans, wheat, and corn are also important crops. Cattle are the primary ranch animal. The agricultural land across the BTES is extremely fertile because it consists of sediment deposited from the Mississippi River. The BTES's deltaic formation, however, also makes it prone to flooding. In southern areas of the basin, saltwater intrusion can be highly detrimental to crop yield and flooding can cause cattle mortality (Barry, 1998; CPRA, 2017).

RECREATION AND TOURISM

The Barataria-Terrebonne estuary provides immense value for tourists and those seeking outdoor recreation. Visitors can engage in ecotourism activities including paddle sports, birdwatching, and fishing within the basin's bayous and waterways. Recreational crawfishing with nets or wire traps is a significant draw for residents in the springtime. Along the coast, tourists can charter offshore vessels to fish for desirable finfish species including snapper, drum, amberjack, and tuna.

The estuary is an important location for both migratory and resident bird species given its location along the Mississippi flyway. Hunting is a popular sport during species-specific hunting seasons and public lands within the Barataria-Terrebonne estuary watershed contain of a diverse variety of habitat types for those seeking to hunt landbound game species. In the air, migratory bird and waterfowl including dove, duck, geese, woodcock, and teal are popular prey species during the fall and winter months.

Bayou Lafourche during the annual BTNEP paddle. Image: Lane Lefort Photography and the Barataria-Terrebonne National Estuary Program

Image: The Water Institute of the Gulf


Image: The Water Institute of the Gulf

CHAPTER 2

Climate Change in Coastal Louisiana

RISING TEMPERATURES AND PRECIPITATION

The BTES is a humid subtropical estuarine-wetland ecosystem with an average annual temperature of 20.4 ± 0.1°C and significant rainfall throughout the year, 1584 ± 22 mm/yr (NOAA National Centers for Environmental Information, 2020). BTES salinity is therefore directly influenced by precipitation and runoff but since the bays are coastal and bound on the west by the Atchafalaya River and on the east by the Mississippi River, variations in salinity are dominated by tidal fluctuations and also changes in river discharge that is propagated upwards by tides and wind (Reyes et al., 2003; Swenson, 2003). Mississippi River discharge peaks in the spring (~22,000 m3 s-1 in April), and is lower in the fall (~6,000 m3 s-1 in September) while mean coastal water levels measured at Grand Isle have two peaks in May-June and September-October, the latter being the larger, and is lowest in January (Swenson, 2003). The hottest and wettest month is July while the coolest month is January, and the driest month is August (Louisiana Climate, n.d.).

By the year 2100, seasons in Louisiana are predicted to have a ± 1.7°C change in average temperatures, with colder falls and winters, and warmer springs and summers, and a 10% increase in precipitation in only the summer and fall seasons (Swenson, 2003). Changes in streamflow are unknown as models produce opposing results. Climatic changes may counteract each other, for example, a

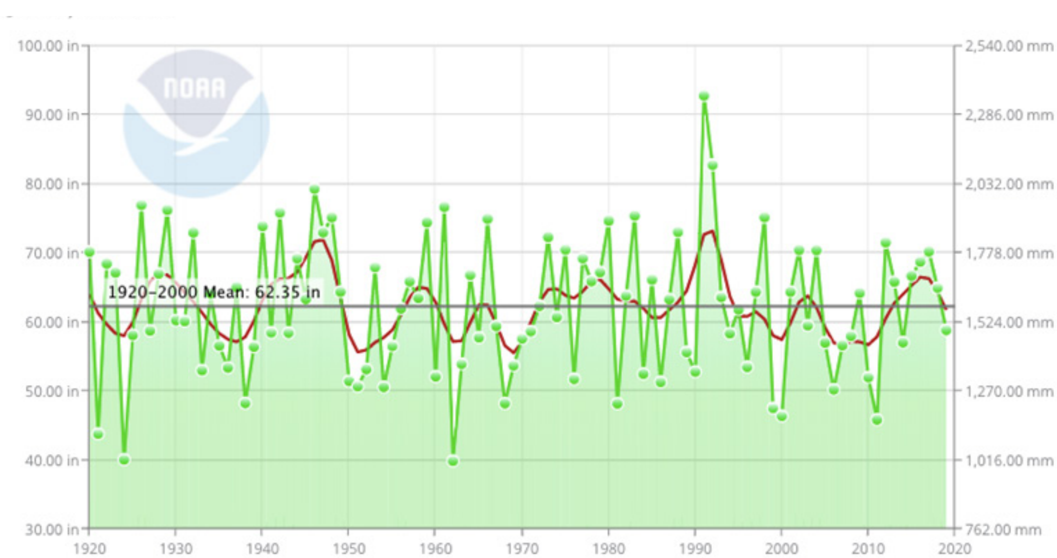


Figure 4. Louisiana Climate Division 9 Precipitation. Source: (NOAA National Centers for Environmental Information, 2020)

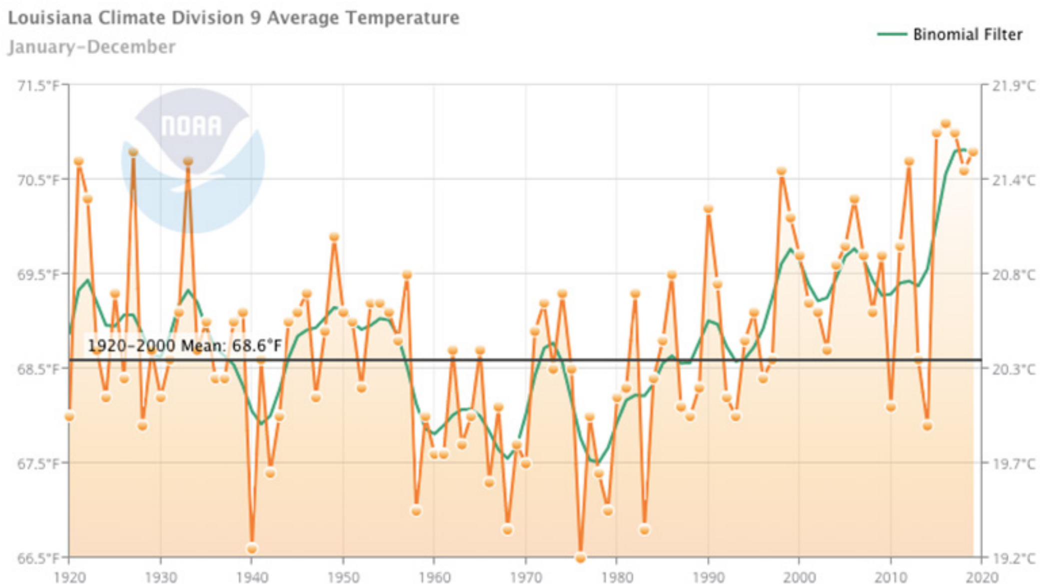


Figure 5. Louisiana Climate Division 9 Average Temperature. Source: (NOAA National Centers for Environmental Information, 2020)

decrease in precipitation may increase bay salinity, but an increase in river flow during this same period might offset the increase. At the same time, some models show patterns of precipitation-evaporation that indicate a possible shift in the salinity zones further south by 10-20 km. Yet, sea level is expected to rise by 30 cm by 2100 and salinity is expected to increase by 1-3 ppt in Barataria Bay (Swenson, 2003).

STORMS AND HURRICANES

While there is high uncertainty about the effects of climate change on hurricane frequency, under all modeled future scenarios there is a projected increase in frequency of major hurricanes, Category 3 and up, with two-thirds of hurricane damage to be felt in Texas, Louisiana, and Florida (Dinan, 2017). This aligns with climate predictions of increased sea surface temperatures, tropospheric water vapor, and rates of sea level rise (Knutson et al., 2015). Coastal Louisiana is projected to have the highest increase in sea level, 0.85 m (2.8 feet), by 2100 under current conditions (Dinan, 2017; Smith et al., 2010). The region is susceptible to flooding from hurricane storm surge due to its low elevation and topography, with low land to water ratios. In addition, its geometric and hydrodynamic complexity make it difficult to accurately model hurricane-induced flooding. Coastal flooding is driven by wind, atmospheric pressure gradients, tides, river flow, short-crested wind waves, and rainfall (Westerink et al., 2008). BTES's barrier islands and coastal marshes do create a zone of friction that slows the winds and waters of these storms (Smith et al., 2010), but storm surge effects are also worsened by the loss of coastal forests since 1930 (Siverd et al., 2019).

Frontal passages and tropical storms often result in large magnitude (≥ 5 ppt) but relatively short duration

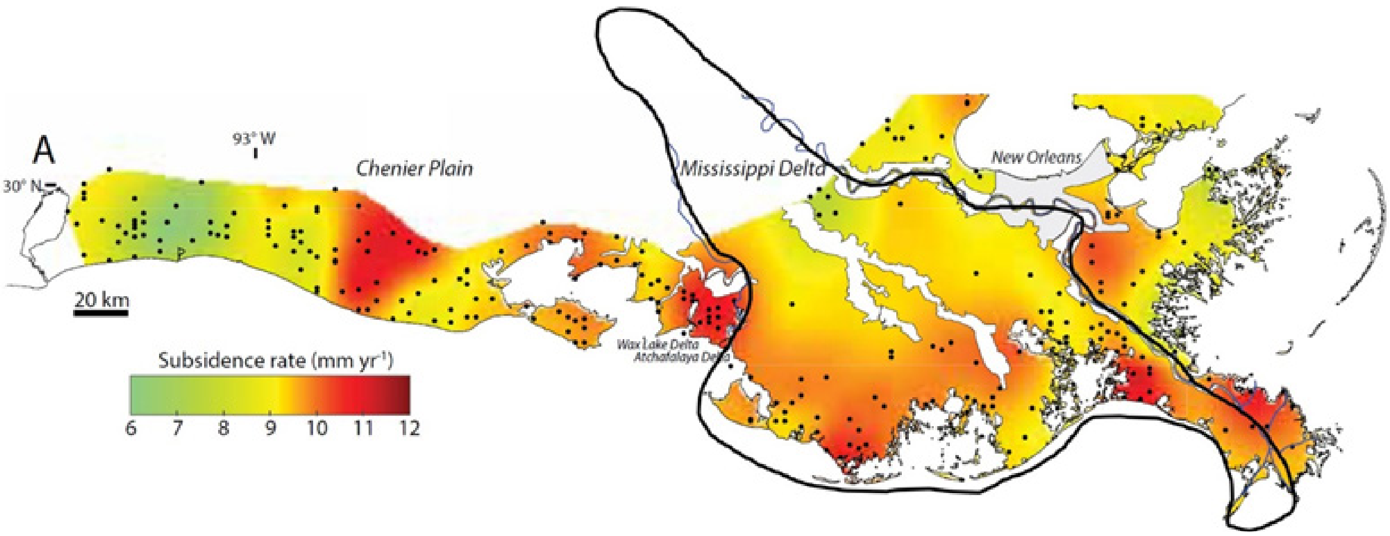


Figure 6. An interpolated map of subsidence rates in coastal Louisiana, where BTES is outlined in black. This map represents both shallow deep subsidence rates. The shallow subsidence rates are based on 6-10 years of data as measured by 274 Coastwide Referencing Monitoring System stations (Karegar et al., 2015; Nienhuis et al., 2017).

(~3 days) salinity pulses in the system (Swenson, 2003). The magnitude of the marsh response to the pulse is very different based on salinity zonation, as the plants in fresh to intermediate marshes have lower salt tolerances therefore storm-driven seawater tends to damage or kill aboveground vegetation. However, coastal wetlands tend to recover quickly, with this salt-burning effect lasting only one or two growing seasons, but geomorphic changes to the landscape are longer lasting (Guntenspergen et al., 1995; Morton & Barras, 2011). Shoreline erosion from a storm is almost always permanent, and the wetland area seldom recovers naturally. Land loss in the BTES, triggered by two hurricanes in 2005, continues today in areas that were severely impacted. Hurricane Katrina made landfall on the eastern edge of the BTES on August 29, 2005 and then, just under a month later, Hurricane Rita made landfall in western Louisiana. In the Barataria Basin, 11,520 acres (18 mi^2, 47 km^2) of land were converted to water, and an additional 12,160 acres (19 mi^2, 49 km^2) of land were lost in the Terrebonne Basin (Barataria-Terrebonne National Estuary Program, 2010). In the last decade, Lake Boudreaux in Terrebonne Parish experienced shoreline erosion rates ranging as high as 15 to 25 m/yr (49 to 82 ft/yr). Interior ponding is occurring in the fresh floatant marshes and, on the shoreline, the magnitude of erosion of Gulf saline marshes exceeds those along the bay shores or interior water bodies surrounded by brackish, intermediate, or fresh marshes (Barras et al., 2003; Morton & Barras, 2011). These hurricanes not only greatly altered BTES ecosystems, but displaced BTES residents, and disrupted the local, regional, and national economy (Barataria-Terrebonne National Estuary Program, 2010).

SUBSIDENCE

Subsidence is the process of land sinking due to natural and/or man-made causes. In coastal Louisiana, there are both shallow and deep mechanisms that drive subsidence. Generally, on river deltas, the compaction of the sediment deposited by a river is a primary driver of subsidence (van Asselen et al., 2009). Compaction is when the sediment is compressed by the weight of materials above it – all the spaces between the sediment particles that are filled by air or water are essentially squeezed out. On the Mississippi River Delta, this shallow compaction or subsidence typically ranges from 1 to 10 mm/yr (Meckel et al., 2006; Penland & Ramsey, 1990; Shinkle & Dokka, 2004). Higher estimates are usually found closest to areas with the thickest sediment deposits with high organic content, such as on the Bird's Foot Delta where the mouth of the river has been depositing large quantities of sediment throughout the Holocene (the current geologic epoch of the last ~11,650 years) (Roberts et al., 1994).

Subsidence rates attributed to deeper geologic processes, (e.g., tectonics and glacial isostacy) depend on the local geologic framework and history. In coastal Louisiana, subsidence rates driven by deeper geologic mechanisms are generally estimated to be on the sub-millimeter range annually (i.e., 0-1 mm/yr), or one order of magnitude lower than shallow subsidence rates (Yuill et al., 2009). The mass loading from large quantities of deposited sediment over time can cause the lithosphere (the crust and upper mantle of the earth) to flex downward leading to general subsidence in the zone of the flexure. Further, the growth and progradation of the deposited sediment can create vertical faults within the substrate. Areas located on the sunken margin of these faults could experience relative subsidence. Both of these and related tectonic processes occur in coastal Louisiana (Yuill et al., 2009). Glacial isostatic adjustment is the process by which landmasses rebalance after the pressure from the mass of an ice sheet has been lifted. This is similar to how a mattress surface readjusts after getting up from it. After the Laurentide ice sheet retreated approximately 16,000 years ago, the landmass that it covered in the Northern Hemisphere (e.g., Canada, and the Midwest and the Northeast US) has been gradually uplifting or rising (Mitrovica & Milne, 2002). Meanwhile, the landmass that lay beyond the perimeter of the ice sheet, including Louisiana, is still sinking and is therefore contributing to deep subsidence (Gonzalez & Törnqvist, 2006).

In addition to these natural causes of subsidence, man-made changes to the landscape can significantly increase rates of subsidence on a localized scale. Artificial drainage and the belowground extraction

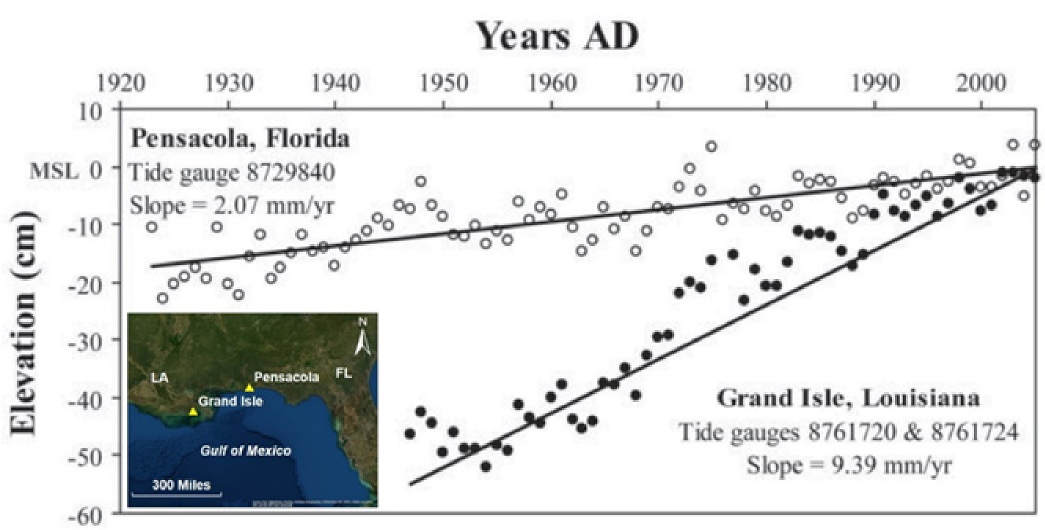


Figure 7. Relative sea level rise trends. The trend for relative sea level rise is measured by two tide gages normalized to present mean sea level in the Gulf of Mexico: The Grand Isle gage in coastal Louisiana and the Pensacola gage in Florida (figure from (Gonzalez & Törnqvist, 2006).

LUMCON's main facility in Cocodrie, Louisiana. Image: The Water Institute of the Gulf

of oil, gas, and water are important economic activities in coastal Louisiana, but they contribute to the compaction of sediment (Gonzalez & Törnqvist, 2006; Kolker et al., 2011).

RELATIVE SEA LEVEL RISE

Understanding subsidence is critical for assessing rates of relative sea level rise. This is especially important in coastal Louisiana where subsidence rates are among the highest in the world (Relative Sea Level Trend: 8761724 Grand Isle, Louisiana, 2019). Relative sea level rise is the combined measurement of global eustatic sea level rise and subsidence. The high spatial variability of subsidence rates in coastal Louisiana is reflected in relative sea level rise rates. An illustration of this can be seen by comparing two tide gages in the Gulf of Mexico. One tide gage is in Pensacola, Florida, where the land surface does not experience significant subsidence, and the other tide gage is in Grand Isle, Louisiana, which is in the BTES and is located where some of the highest rates of subsidence are estimated (Gonzalez & Törnqvist, 2006). The average rate of relative sea level rise in Pensacola is 2.07 mm/yr. This is close to the global eustatic SLR of 1.7□0.2 mm/yr. Meanwhile, the Grand Isle average rate of relative sea level rise is 9.39 mm/yr, which is nearly five times higher than in Pensacola.

OCEAN ACIDIFICATION

In the Barataria-Terrebonne estuary, a major contributor to acidification has been the nutrient pollution that the Mississippi River carries into the Gulf of Mexico. Runoff from farms, lawns, and sewage systems pollutes the Mississippi River with excess nutrients. The pollution causes an overgrowth of algae (called algae blooms) which leads to the release of carbon dioxide, and the subsequent acidification of the waters (Ekstrom et al., 2015).

Ocean acidification poses a high risk to the habitats and economy in the Barataria-Terrebonne estuary. The acidification reduces the availability of minerals in the water, which hinders the ability for shellfish to build their shells. Because a significant sector of south Louisiana's economy relies on the seafood industry, the livelihoods and employment of fishermen are at risk (Ekstrom et al., 2015).

Image: The Water Institute of the Gulf

CHAPTER 3

Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans

The BTNEP Climate Change Adaptation Plan was developed through a process of surveying, interviewing, and engaging with key stakeholders identified through the BTNEP Management Conference. This group included both local and technical knowledge experts with broad expertise on the BTES and the threats and challenges that it faces. Development of the adaptation plan, outlined in the next chapter, followed a step-by-step process established by the Climate Ready Estuaries Program under the U.S. Environmental Protection Agency's National Estuaries Program (U.S. Environmental Protection Agency, 2014). This process allows organizations such as BTNEP to systematically identify risks, carry out vulnerability assessments, and develop an estuary-wide adaptation plan to address those critical impacts resulting from climate change. The final output of this process is step-by-step plan of action to address specific climate change impacts such as those described in earlier chapter of this report (Bauzá-Ortega, 2015).

The Workbook, a tool developed by the Climate Ready Estuaries Program, is intended to help National Estuary Programs identify a suite of risks associated with climate change, carry out vulnerability studies, and develop a plan for adapting to the impacts caused by climate change (Bauzá-Ortega, 2015). The Workbook guides researchers through ten key steps leading to the development of a vulnerability assessment and an adaptation plan for the estuary. The outputs of this analysis will allow BTNEP to develop, implement, and monitor adaptation actions. The first five steps of the process are designed to capture the most locally relevant risks that climate change will pose to the BTES with a goal of assessing the estuary's vulnerability. During this vulnerability assessment phase, stakeholders identified a number of risks that the estuary my face and decided which of these risks to focus on based upon the likelihood of the risk occurring, the level of consequences, and the scale of impact associated with each risk. Once all possible foreseeable risks were identified, these were ranked and prioritized. High priority risks are those that are expected to have critical consequences and are currently impacting the estuary (Bauzá-Ortega, 2015). The action plan phase of research, outlined in steps 6-10, focus on designing, implementing, and monitoring concrete actions. The action plan includes the tasks that BTNEP will perform in order to mitigate climate-change impacts. Some of these actions may are direct actions that BTNEP will lead while other actions are currently being undertaken by state and local partners. The action plan explains the 20 pertinent climate change risks that BTNEP and its partners will address. The next chapter (Chapter 4) will describe BTNEP's process for completing their vulnerability assessment and adaptation plan.

Vulnerability Assessment

1 — COMMUNICATION AND CONSULTATION
Informing key people about the vulnerability assessment and asking for input

2 — ESTABLISHING THE CONTEXT FOR THE VULNERABILITY ASSESSMENT
Identifying organizational goals that are susceptible to climate change

3 — RISK IDENTIFICATION
Brainstorming about how climate stressors will interact with your goals

4 — RISK ANALYSIS
Developing an initial characterization of consequences and likelihood for each

5 — RISK EVALUATION: COMPARING RISK
Using a consequence/probability matrix to build consensus about each risk

Adaptation Plan

6 — ESTABLISH THE CONTEXT FOR ACTION PLAN
Identifying opportunities and constraints that will affect your adaptation decisions

7 — RISK EVALUATION: DECIDING ON A COURSE
Deciding at a high level whether you will mitigate, transfer, accept or avoid each risk

8 — FINDING ADAPTION ACTIONS
Finding mitigating actions for further investigations

SELECTING ADAPTION ACTIONS
Selecting a set of risk reducing actions to implement

9 — PREPARING AND IMPLEMENTING AN ACTION PLAN
Creating a plan to track mitigating actions and which risks they address

10 — MONITORING AND REVIEW
Keeping track of your actions and maintaining your vulnerability assessment

Figure 8. A step-by-step process for completing a vulnerability assessment and adaptation plan, as described in the U.S. EPA's Being Prepared for Climate Change: A Workbook for Developing Risk-based Adaptation Plans

Image: The Water Institute of the Gulf

Image: The Water Institute of the Gulf

CHAPTER 4

Steps for Actions: Barataria-Terrebonne Estuary Climate Change Adaptation Plan

Step 1: Communication and Consultation

The objective of this first step is to involve citizens, groups, agencies, and other interested parties in the development of a vulnerability analysis and subsequent adaptation plan, and to inform the public of the importance of developing such a plan (Bauzá-Ortega, 2015). During this step, BTNEP and the Water Institute directly engaged with the BTNEP Management Conference, a committee of local and technical knowledge experts drawn from industry and business, fisheries, agriculture, oil and gas, government agencies, individual citizens, landowners, civic organizations, hunters, scientists, engineers, environmentalists, economists, and urban planners. The Management Conference was originally convened in 1990 to help guide BTNEP and produce open and frank discussions about critical coastal management issues facing coastal Louisiana and the estuary.

Initial consultation with the Management Conference took place during a regularly scheduled BTNEP quarterly meeting. During this meeting, the Water Institute presented information on the Climate Change Adaptation Planning process, the EPA Workbook, and the role that the Management Conference would play in the vulnerability assessment. The quarterly meeting was an ideal time for this presentation because of the high level of Management Conference attendance and the opportunity to have a public forum about the topic of adapting to climate change. During this meeting, many members of the BTNEP Management Conference were supportive of helping develop the adaptation plan by (1) identifying the most pressing climate change risks affecting the estuarine system that they live and work in and (2) developing a plan to address these risks.

Step 2: Establishing the Context for the Vulnerability Assessment

To determine the scope of the vulnerability analysis and adaptation plan, the Water Institute first considered the BTNEP goals that may be compromised by climate change. BTNEPs goals were set during the organization's founding in 1992. Their goals underlie their Action Plans for conservation management.

The goals relevant to climate change adaptation include:

- Preserve and restore wetlands and barrier islands
- Realistically support diverse, natural biological communities
- Develop and meet water quality standards that adequately protect estuarine resources and human health
- Promote environmentally responsible economic activities that sustain estuarine resources
- Implement comprehensive education and awareness programs that enhance public involvement and maintain cultural heritage
- Support and create clear, fair, practical, and enforceable regulations
- Develop and maintain multi-level, long-term, comprehensive watershed planning
- Be compatible with natural processes
- Forge common-ground solutions to estuarine problems
- Formulate indicators of estuarine ecosystem health and balance estuary use

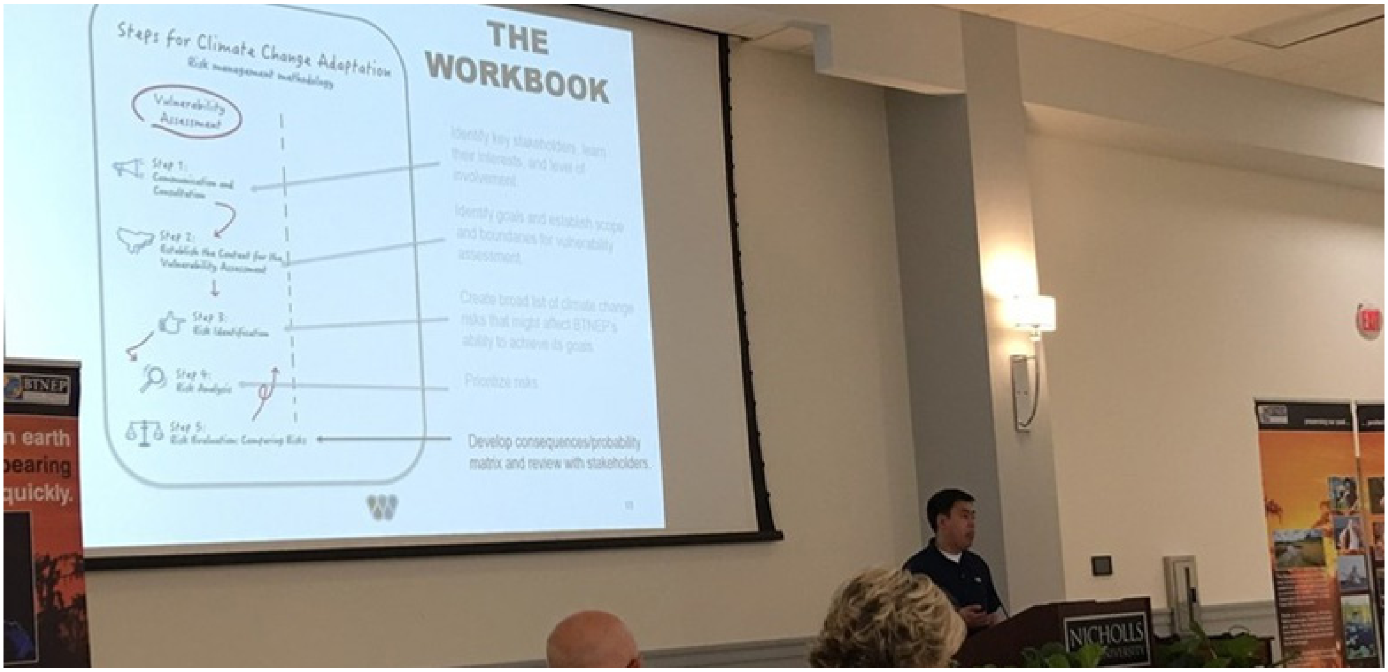
Step 3: Risk Identification

The Water Institute identified a range of possible risks that the estuarine system may face due to climate change. They did this by finding risks that may be associated with BTNEP's goals in the face of a number of climate change stressors identified by the EPA. The climate change stressors analyzed in this study include:

- Warmer summers
- Warmer winters
- Warmer water
- Increasing drought
- Increasing storminess
- Sea level rise
- Ocean acidification

To ensure that a comprehensive range of possible risks were identified, the Water Institute underwent the following steps to develop the list:

1. Choose a BTNEP goal, for example, "Preserve and restore wetlands and barrier islands"



The Water Institute of the Gulf Engaging with the BTNEP Management Conference. Image: The Water Institute of the Gulf

2. Choose a climate change stressor (from EPA Workbook), for example, "Warmer summers"
3. Identify the associated risks. For example: "more stressed native species allow for an increased likelihoood of the establishment of invasive species," or "an increased threat to fishes, crustaceans, and amphibians as they exceed their biological limits for temperature and dissolved oxygen."
4. Validate risks with key stakeholders by having select members of the BTNEP staff, and university collaborators, review and modify the comprehensive list of risks.

After completing these four steps, a final list of 152 risks associated with climate change were identified. Tables 6-Table 12 in the Appendix outline the risks identified.

Step 4: Risk Analysis

To narrow down the comprehensive list of 152 climate change risks, a survey – consisting of a matrix of drop-down menus for each climate change stressor – was developed so that members of the BTNEP Management Conference could evaluate and prioritize each risk. A total of 21 Management Conference members took the survey. Respondents ranked the severity of each risk based upon four criteria: Likelihood of occurrence, consequences

Table 1. Survey Instructions

Survey Instructions: Please prioritize each risk using the dropdown option that appears next to the cell when you click on it. Prioritizations are based on the following criteria: the likelihood of the risk actually occurring (likelihood of occurrence), the effects of the risk on BTNEP's goals (consequences of impact), the geographic area that the risk will affect (how widespread), and when the impact of the risk is expected to occur (over what time period).				
	Likelihood of occurrence	**Consequences of impact**	**How widespread**	**Over what period of time**
Low	Unlikely to occur.	Life will go on, could adjust.	Limited-Site specific (e.g. small structure (dock, bridge, sewage plant).	30+ years away.
Medium	Moderate chance of occurrence.	Moderate impact.	Regional-Place or region (e.g. community, harbor, state park, wildlife refuge, sub-watershed).	10-15 years.
High	Already occurring.	Major disruption; goal out of reach or unattainable.	Widespread-Extensive (most of the watershed or most of the estuary).	Already occurring/ imminent or 0-10 years.

of impact, how widespread, and time period. There were three options for each criterion which could be categorized as low, medium, or high. Table 1 outlines the survey instructions.

Step 5: Risk Evaluation: Comparing Risks

To complete the vulnerability assessment and transition to building an adaptation plan, risks were prioritized based upon the survey results. To analyze all survey results, the "low," "medium," "high" categories were translated into numbers (1, 2, 3) that could be averaged and given a grade (A, B, C). To give each risk a grade, the average score for each risk was divided into one of three evenly distributed groups. Averages ranging from 1.0-1.67 received an A grade; 1.68-2.33 received a B, and 2.34-3.0 were given a C grade.

Risks that scored a "C" for the following categories are outlined in Table 1: Probability of occurring, consequences, and widespread in spatial scale. A total of 20 risks made it to the next round of consideration (Table 2).

Step 6: Establishing the Context for the Action Plan

To establish the context for the Action Plan, the Water Institute did five in-depth interviews with BTNEP Management Conference members to get further clarification on the list of 20 risks outlined in Table 1. The interview participants were prompted to clarify the list of 20 risks to reflect the needs of the Barataria-Terrebonne estuary more accurately and specifically. Interviewees were also prompted to identify potential responsible parties and adaptation actions that could be associated with each of the risks. The clarified list of 20 most important risks was turned into a survey for BTNEP staff to review and decide on a course of action. Information from the interviews about potential responsible parties and adaptation actions were used to supplement the second round of survey results.

Table 2. List of Most Important Risks

Increasing storminess will result in…	
1.	Frequent flooding in areas with inadequate stormwater infrastructure.
2.	Higher insurance rates, forcing residents to be uninsured.
Sea level rise will result in…	
3.	Habitat change, which will ultimately lead to habitat loss for fish, birds, and plants.
4.	A change in nesting areas suitable for sea turtles, aquatic birds, and other marine creatures.
5.	A change in the distribution and range of fish and crustaceans due to intrusion of sea water into fresher systems.
6.	Areas of brackish marsh transitioning to salt marsh.
7.	Increases in salinity levels, followed by worsening of the symptoms of eutrophication, which include hypoxia and harmful algal blooms.
8.	An increase in the concentration of microbes, which will lead to an increased likelihood of disease transmission for humans (from consuming infected seafood or from wound exposure in marine environments).
9.	Wetland drowning and increased shoreline armoring, causing limited landward retreat of the wetlands.
10.	The loss of ecosystem services associated with barrier islands and wetland areas (storm damage reduction, nature-based tourism, support for agriculture and aquaculture, and carbon sequestration).
11.	An increase in the severity of high tide flooding and storm surges.
12.	An increase in coastal flooding and an increase in insurance costs to which will force residents to abandon or sell their coastal properties.
13.	An increase in the frequency of high tide flooding and storm surges.
Warmer air temperatures will result in…	
14.	Changes in plant and animal communities with increased numbers of invasive species.
Warmer waters will result in…	
15.	Fishery harvesters having to adapt their practices due to changes in habitat for recreational and commercially important species.
16.	An increase in fish and marine outmigration or die off due to hypoxia and harmful algal blooms.
17.	Aquatic organisms experiencing an increase in physiological stress and reaching their thermal limits.
18.	An increase in abundance of invasive aquatic plants and animals.
19.	An alteration in the distribution of fish and shellfish stocks which will decrease the stability of fishermen's' livelihoods.
20.	An increase in the intensity of hurricane events and an increase in the frequency of Category 4 and 5 storms.

Step 7: Deciding on a Course of Action

BTNEP staff reviewed the climate change risks (outlined in Table 2) in a survey that prompted them to decide whether to mitigate, transfer, accept, or avoid each risk. If a survey respondent selected to "mitigate" or "transfer" a risk, they were prompted to provide additional detail on potential mitigation actions that could be taken by BTNEP or the responsible party for that action. A total of 6 staff members took the survey.

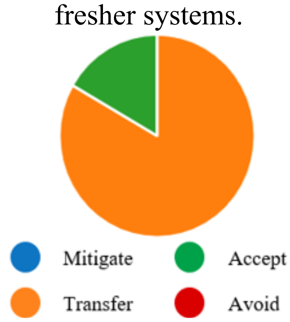
- **MITIGATE:** BTNEP will take action to reduce the likelihood and/or consequence of the risk and allocate resources or time to implement this action. Note that there may be some risks that BTNEP should mitigate that are poorly understood. A research project may need to be the first mitigating action.
- **TRANSFER:** BTNEP will assign responsibility for reducing a risk to an outside organization and will affirm that this organization allocates resources to mitigate the risk. This may mean that another agency is already taking hazard mitigation actions that would have the co-benefit of reducing BTNEP's risk. This may also mean that BTNEP transfers a risk by partnering with another organization or by making a financial contribution to another organization's mitigation project.
- **ACCEPT:** BTNEP decides that it is not currently feasible for them or their partners to mitigate this risk or develop an adaptation plan. Accepting a risk means that BTNEP will continue to monitor the risk and deal with it if or when impacts occur or address the risk at a later time as more resources or information become available.
- **AVOID:** BTNEP decides to avoid a risk by administratively narrowing it's organizational goals rather than addressing that risk. Avoiding a risk does not mean that the impacts go away. Rather, it means that BTNEP will move away from this objective and not put resources or time towards addressing it.

Step 8: Finding and Selecting Adaptation Actions

Upon completion of the survey, BTNEP staff convened with the Water Institute via an online workshop to discuss the survey results and come to a consensus on the adaptation actions for each risk. The final consensus for most adaptation actions are reflected the survey results (pie charts in Table 3), except for the risks that BTNEP ultimately decided to mitigate or to avoid (second column in Table 3).

Coastal ecologist taking field notes about a salt marsh, which are important habitats as they sequester carbon. Image: The Water Institute of the Gulf

Table 3. Adaptation Actions Selected for Each Risk (quotations from Barataria-Terrebonne National Estuary Program, 2018)

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Sea level rise will result in areas of brackish marsh transitioning to salt marsh.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for Ecological Management Action Plans 1, 2, and 3 (EM-1, EM-2, EM-3) in the 2018 BTNEP Comprehensive Conservation and Management Plan (CCMP; Barataria-Terrebonne National Estuary Program, 2018). **EM-1 Hydrologic Restoration and Management** CWPPRA will lead an effort to "…improve hydrology through the effectual use of the freshwater, sediments, and/or nutrients that already reach the basins. [And] to "…stabilize water levels and salinity to provide conditions conducive to the establishment and growth of emergent and submergent marsh plants." **EM-2 River Reintroduction** CPRA, USACE, LDNR, and the CWPPRA Task Force will lead an effort to "…use riverine resources of freshwater and sediment from the Mississippi and Atchafalaya Rivers in order to decrease salinities and preserve and/or create marshes." **EM-3 Freshwater Reintroduction into Bayou Lafourche** BLFWD , CPRA, USACE, EPA, USFWS, and NRCS will lead an effort to "…support and encourage reintroduction of Mississippi River flow into Bayou Lafourche in order to bring freshwater and sediments to the BTB marshes to help address coastal land loss and to ensure adequate consumptive freshwater supplies by combating saltwater intrusion."
Sea level rise will result in a change in the distribution and range of fish and crustaceans due to intrusion of sea water into fresher systems.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-1, EM-2, EM-3 in the 2018 BTNEP CCMP.

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Sea level rise will result in wetland drowning and increased shoreline armoring, causing an increase in open sea and a loss of wetland areas.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-4 and EM-6 in the 2018 BTNEP CCMP. **EM-4 Beneficial Use of Dredged Material and Dedicated Dredging** The USACE New Orleans District, the CWPPRA Task Force, CPRA, and the state Office of Coastal Management will "…make use of material when dredging activities or dedicated dredging occurs within or adjacent to the BTES in order to create, maintain, and/or restore marsh, coastal ridges, and islands." **EM-6 Shoreline Stabilization, Induced Sediment Deposition, and Living Shorelines** CPRA, USACE, and CWPPRA will "…facilitate maintaining and restoring existing marshes and swamps by reducing shoreline erosion along bays, lakes, canals, and bayous… trap or induce sediment deposits in order to maintain and restore existing marshes and swamps as well as build new marshes… [and] construct and maintain living shorelines for shore erosion control wherever possible and feasible in order to create and enhance growth and sustain habitat that is naturally resistant to erosion."
Sea level rise will result in an increase in coastal flooding and an increase in insurance costs to which will force residents to abandon or sell their coastal properties.  	**Avoid the risk.** Avoid the risk. BTNEP does not administratively handle insurance costs, or the abandonment or selling of properties. This risk has been more exclusively addressed by the LASAFE program and FEMA.
Increasing storminess will result in higher insurance rates, forcing residents to be uninsured.  	**Avoid the risk.** Avoid the risk. BTNEP does not administratively handle insurance rates. This risk is more exclusively an issue for parish governments in cooperation with FEMA to enhance local hazard-mitigation plans.

<table>
<tr><th>Initial Decision from Survey</th><th>Final Decision from Workshop: Actions and Lead Agency(ies) Responsible</th></tr>
<tr><td>Sea level rise will result in increases in salinity levels, followed by worsening of the symptoms of eutrophication, which include hypoxia and harmful algal blooms.


</td><td>
Transfer the risk
Transfer the risk to the lead agencies responsible for EM-10, EM-11, EM-12, and EM-14 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the agencies responsible for implementing EM-12 and EM-14.

EM-10 Improvement of Water Quality Through the Reduction of Sewage Pollution
LDH, LDEQ, LDWF, LDNR, USCG, local governments, and SCPDC will "…reduce fecal coliform counts, pathogens, nutrients, and organic matter in the BTES waterbodies attributable to discharges of human waste from inadequate or poorly-maintained sewage treatment plants, rural homesites, unsewered communities, commercial and recreational vessels, and waterfront camps"

EM-11 Reduction of Agricultural Pollution
LDEQ, LDAF, USDA-NRCS will "…maintain water quality standards that adequately protect estuarine resources from agricultural nonpoint source pollutants."

EM-12 Improvement of Water Quality Through Stormwater Management
BTNEP, local parish governments, and local city governments will "…reduce the negative impacts on water quality that current stormwater disposal practices may produce… reduce loadings of nutrients, fecal coliform bacteria and pathogens, and other pollutants in waterways… [and] enhance wetland vegetation with inputs of nutrients, sediments, and freshwater from stormwater runoff." BTNEP can help apply for grants that would support stormwater redirection projects, stormwater infiltration basin projects, and urban stream restoration projects, which would allow local parish governments do the construction and maintenance for these projects.

EM-14 Assessment of Harmful Algal Blooms (HABs)
This Action Plan has many responsible agencies. LDAF, LDEQ, NRCS, EPA, and BTNEP are responsible for implementing best management practices in watersheds. LDAF, LDH, LDEQ, LDWF, USDA, and U.S. Food and Drug Administration (FDA) are responsible for preparedness to minimize human impact from toxic or harmful algal bloom events. BTNEP, LDAF, LDH, LDEQ, LEEC, LDWF, LUMCON, The Water Institute of the Gulf, LDOE, Louisiana Sea Grant College Program, EPA, National Environment Programs, Gulf of Mexico Program, and Gulf of Mexico Alliance-Private aquariums along Gulf Coast are responsible for promoting public awareness and understanding.

Together, the agencies responsible for EM-14 will work to "…minimize the human health impacts of HABs in the BTES… reduce the frequency and intensity of HABs within the BTES by supporting [Best Management Practices] of watershed nutrient management… build partnerships between research scientists and agency resource managers to help prepare for and respond to some HABs whose sources can and cannot be managed from within BTES to help reduce threats to marine organisms, human health, and economic well-being… [and] increase public awareness of HABs' threats"
</td></tr>
</table>

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Warmer waters will result in an increase in fish and marine outmigration or die off due to hypoxia and harmful algal blooms.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-10, EM-11, EM-12, and EM-14 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the agencies responsible for implementing EM-12 and EM-14.
Sea level rise will result in habitat change, which will ultimately lead to habitat loss for fish, birds, and plants.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-5 and EM-15 in the 2018 BTNEP CCMP. **EM-5 Preservation and Restoration of Barrier Islands** CPRA, USACE, and the CWPPRA Task Force will "…preserve and restore barrier islands in order to protect environmental and economic resources." **EM-15 Protection and Enhancement of Native Biological Species** LDWF, LDNR, CPRA, LDAF, USDA, NRCS, USFWS, USGS, and NOAA's NMFS will "…support conservation efforts for ecological succession patterns of plant diversity from up-basin to down-basin within each of the habitat zones of the BTB delta ecosystem… build a framework that encourages landowners to manage their land in a way that maximizes its suitability as habitat for pollinators… support conservation efforts to maintain the diverse recreational and commercial invertebrate and vertebrate species harvested for pleasure and profit… support conservation measures that maximize available natural habitats that maintain healthy populations of migratory and resident birds across the BTB system… support conservation efforts to maintain the diverse amphibian, reptile, and mammal populations… [and] support recovery and conservation efforts for threatened and endangered species."
Sea level rise will result in a change in nesting areas suitable for sea turtles, aquatic birds, and other marine creatures.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-5 and EM-15 in the 2018 BTNEP CCMP.

<table>
<tr><th>Initial Decision from Survey</th><th>Final Decision from Workshop: Actions and Lead Agency(ies) Responsible</th></tr>
<tr><td>Warmer waters will result in aquatic organisms experiencing an increase in physiological stress and reaching their thermal limits.

</td><td>Accept the risk
Accept the risk and monitor it over time.

While BTNEP and their partners actively study and address changes in terrestrial and aquatic habitats, it is not currently feasible for any of these organizations to address warming waters. While no action can be taken to address this risk during this time, BTNEP will monitor the risk as a part of the EM-15 Action Plan in the 2018 CCMP.</td></tr>
<tr><td>Warmer air temperatures will result in changes in plant and animal communities with increased numbers of invasive species.

</td><td>Mitigate the risk
Mitigate the risk through the EM-16 Action Plan in the 2018 BTNEP CCMP.

EM-16 Reduction of Impacts from Invasive Species
BTNEP with support from USDA, APHIS, USGS, Federal Native Plant Conservation Committee, USACE, USFWS, LDAF, LDWF, LSU Cooperative Extension Service, and CWPPRA will "…prevent and reduce negative impacts caused by the proliferation of invasive exotic species in order to protect the native organisms and resources of the BTE."</td></tr>
<tr><td>Warmer waters will result in an increase in abundance of invasive aquatic plants and animals.

</td><td>Mitigate the risk
Mitigate the risk through the EM-16 Action Plan in the 2018 BTNEP CCMP.</td></tr>
</table>

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Warmer waters will result in an alteration in the distribution of fish and shellfish stocks which will decrease the stability of fishermens' livelihoods.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for "Sustained Recognition" and "Coordinated Planning and Implementation" Action Plans 8 and 3 (SR-8 and PE-3) in the 2018 BTNEP CCMP. The BTNEP MC has a supporting role in the plan to address this risk as the agency responsible for implementing PE-3. **SR-8. Cultural Heritage and Lifeways.** This Action Plan has many lead implementers, which include parish libraries, local and parish historical societies and museums, BTES schools, the USNPS and Cultural Resources Climate Change Strategy, the NSU Center for Bayou Studies, Louisiana Sea Grant, the Lowlander Center, universities, genealogical societies, arts councils, tourist commissions, local and regional governments, and other individuals and organizations presently involved in culturally-based activities. Together, the agencies responsible for SR-8 will "…explore, investigate, and identify the cultural/lifeways connections that improve human resilience due to the vulnerability of the land and water of the BTES… protect the rich cultural lifeways that are connected to the natural resources of the BTES… educate about the historical interaction of BTES residents and the BTE's resources through active research projects that use maps, film, photos, documentaries, oral histories, and other techniques that will document this interaction to preserve the cultural aspects of the region… promote a demand for information that highlights the uniqueness of our cultural heritage through creating and supporting events that attract the attention of scholars, students, and a public audience for the endangered cultural resources nurtured in the BTES… advance greater awareness of the way the lifestyles and unique historical traditions of the BTES are a living classroom that demonstrate the interaction between the region's natural and cultural resources… support the complex dynamics of transition through the preservation and memorialization of community histories when those communities must transition from their traditional lands due to coastal land loss or ecological disasters… to prepare communities to adapt to new coastal lands as successful restoration practices as the natural." **PE-3. Seafood Promotion, Technology, and Marketing** The BTNEP MC will support the "economic survival of seafood harvesting and processing firms operating in the BTES region…[through] education, technology transfer, and new market development… The BTNEP MC will support developing and implementing enhanced public outreach initiatives and partnership opportunities to inform and promote new handling and processing technologies, value-added products, and innovative practices and byproduct uses that maximize the quality and profitability of seafood resources in the BTES region."

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Warmer waters will result in fishery harvesters having to adapt their practices due to changes in habitat for recreational and commercially important species.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for "Sustained Recognition" and "Coordinated Planning and Implementation" (SR-8 and PE-3) Action Plans in the 2018 BTNEP CCMP. The BTNEP MC has a supporting role in the plan to address this risk as the agency responsible for implementing PE-3.
Warmer waters will result in an increase in the intensity of hurricane events and an increase in the frequency of Category 4 and 5 storms.  	**Transfer the risk** Transfer the risk to the lead agencies responsible for CP-2 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the lead agencies responsible for implementing CP-2. **CP-2 Emergency Response, Recovery, and Resiliency** The BTNEP Program Office, BTNEP MC, and the Barataria-Terrebonne Estuary Foundation, will work with NOAA's Hurricane Center, the Louisiana Office of Emergency Preparedness, and FEMA to "…coordinate diverse activities across other Action Plans in the event of disaster response, recovery, and resilience."

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Sea level rise will result in the loss of ecosystem services associated with barrier islands and wetland areas (storm damage reduction, nature-based tourism, support for agriculture and aquaculture, and carbon sequestration). 	**Transfer the risk** Transfer the risk to the lead agencies responsible for PE-1, PE-2, PE-5, and PE-6 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the lead agencies responsible for implementing PE-1, PE-2, and PE-5. **PE-1. Place Based Benefits of the Barataria-Terrebonne Estuary System** BTNEP, the Lafourche Convention and Visitors Bureau, the LDCRT, the Louisiana Travel Promotion Association and its members in the BTES, SLEC, TEDA, and SCPDC will "work collaboratively with regional tourism and economic development entities to assist tourism operators and entrepreneurs to: recognize, understand, and value the rich natural and cultural resources of the BTES… enhance the quality and the quantity of nature based and cultural experiential tourism opportunities and operations in the BTES… [and] support the development and operation of new and existing tourism activities through traditional economic development techniques/education." **PE-2. Scientific Literacy on Water** BTNEP will take the lead in networking to "support development and implementation of enhanced public outreach, based in use of accessible language, interactive dialogue, and respect for local water knowledge and culture." **PE-5. Climate Change as an Economic Driver** BTNEP will collaborate with EPA, NOAA, USGS, CPRA, and the Louisiana Sea Grant College program to "help individuals, businesses, and communities plan for and adapt to projected climate changes, by: supporting and sharing the latest assessments on coastal landscape change and climate-based projections… promoting awareness and understanding of adaptive restoration and protection options and the capacity of these strategies to mitigate changing conditions… developing information and tools to aid residents and businesses on economic decisions related to development, settlement, and risk mitigation… promoting the BTES region as a global leader in the development of coastal restoration technologies and community adaptation approaches for dealing with climate change." **PE-6. Business and Financial Assistance as an Economic Driver** SCPDC, SLEC, the SBDC, the chambers, and local government, and bankers will "… educate business leaders, elected officials, university officials, and the general public about the economic value and potential of BTNEP as a future economic engine for southern Louisiana with relationship to sustainable development… drive economic diversification and stability through the appropriate use of natural resources found in the BTES… identify, catalog, and promote access to financial tools to environmentally friendly businesses; incentive programs that could assist in business formation and growth; and grant program development to assist in programmatic activities related to wetland resources… operate as a conduit linking businesses with resources… identify and promote solutions for any financial and regulatory gaps faced by business… create place-based marketing programs that reinforce the positive messages about the quality of life and economic opportunities in the BTNEP region."

<table>
<tr><th>Initial Decision from Survey</th><th>Final Decision from Workshop: Actions and Lead Agency(ies) Responsible</th></tr>
<tr><td>Sea level rise will result in an increase in the severity of high tide flooding and storm surges.

</td><td>Transfer the risk
Transfer the risk to the lead agencies responsible for EM-7 in the 2018 BTNEP CCMP.

EM-7 Flood Risk Reduction and Coastal Resiliency
USACE New Orleans District, CPRA, and TLCD will “…provide flood risk reduction measures for property, population centers, [and] ecosystems… [and] anticipate, prepare for, and adapt to changing conditions and withstand and recover from disruptions.”</td></tr>
<tr><td>Sea level rise will result in an increase in the frequency of high tide flooding and storm surges.

</td><td>Transfer the risk
Transfer the risk to the lead agencies responsible for EM-7 in the 2018 BTNEP CCMP.</td></tr>
<tr><td>Increased storminess will result in frequent flooding in areas with inadequate stormwater infrastructure.

</td><td>Transfer the risk
Transfer the risk to the lead agencies responsible for EM-13 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the lead agencies responsible for implementing EM-13.

EM-13 Urban Green Spaces
Individual municipalities, individual communities, and BTNEP will “…encourage the creation and growth of wildlife habitats in urban areas… provide additional recreational space for visitors and residents of the Estuary to improve quality of life… augment economic development… improve urban flood control… [and] reduce urban flooding from runoff.”

PE-4 Development at Port Fourchon
GLPC with help from BTEF, Nicholls State University, Louisiana State University, Environmental NGOs and non-profits, CPRA, the energy industry, and media will lead “… the planning and construction of green infrastructure and a holistic approach to resiliency of traditional hard (grey) assets through the construction of natural protective buffers (green infrastructure) throughout the BTES.”</td></tr>
</table>

Initial Decision from Survey	Final Decision from Workshop: Actions and Lead Agency(ies) Responsible
Sea level rise will result in an increase in the concentration of microbes, which will lead to an increased likelihood of disease transmission for humans (from consuming infected seafood or from wound exposure in marine environments).  	**Transfer the risk** Transfer the risk to the lead agencies responsible for EM-8, EM-17, and EM-18 in the 2018 BTNEP CCMP. BTNEP has a supporting role in the plan to address this risk as one of the lead agencies responsible for implementing EM-8, EM-17, and EM-18. **EM-8. Pollutant Identification and Assessment** LDEQ, CPRA, LDH, LDNR, LOSCO, LDWF, LDAF, BTNEP, USEPA, NOAA, USDA, and USGS will "facilitate access to accurate and timely water quality data for the BTES by the public, researchers, and governmental agencies… [and] facilitate access to Geographic Information System (GIS) data and mapping for hydrology, land use, permitted facilities discharging to BTES water bodies, and other related topological parameters that will promote better identification of current or potential water quality impacts." **EM-17. Improvement of Water Quality through the Reduction of Inshore and Marine Debris** The BTPO staff will be the co-lead implementer with the BTNEP MC, EPA, GOMP, Louisiana Sea Grant, LDWF, LDEQ, NOAA, Keep Louisiana Beautiful (KLB), Keep America Beautiful (KAB), LSU, and BTEF will "improve water quality by significantly reducing the amount of trash entering the BTB's water bodies and the ocean through education and awareness activities targeted at students (K-12), parish governments, business communities, and individual citizens." **EM-18. Protection of Drinking Water Sources** LDEQ, LDH, LDNR, USDA, NRCS, LDAF, BTNEP MC, local citizens, and water advisories will "…have a clear delineation of all drinking water sources… identify possible problems and potential sources of contamination including but not limited to toxics, sewage, microplastics, pharmaceuticals, and other emerging contaminates… use BMPs to diminish or eliminate problems… engage citizens in active protection of their drinking water… educate about appropriate actions to protect drinking water in the event of an emergency… support improvement in appropriate training and pay to develop an experienced workforce related to drinking water… participate in the education of public officials about the long term commitment that is needed to properly train certified water operators and related jobs… support appropriate improvements to the water resources infrastructure… [and] support emerging technologies related to protecting drinking water sources."

Table 4. List of Acronyms for Table 3

Acronym	Full Name	Acronym	Full Name
APHIS	Animal and Plant Health Inspection Service	**LEEC**	Louisiana Environmental Education Commission
BLFWD	Bayou Lafourche Fresh Water District	**LOSCO**	Louisiana Oil Spill Coordinators Office
BTEF	Barataria-Terrebonne Estuary Foundation	**LUMCON**	Louisiana Universities Marine Consortium
BTPO	Barataria-Terrebonne Program Office	**NRCS**	Natural Resources Conservation Service
CPRA	Coastal Protection and Restoration Authority	**NMFS**	National Marine Fisheries Service
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act	**NOAA**	The National Oceanographic and Atmospheric Administration
EPA	U.S. Environmental Protection Agency	**SBDC**	Small Business Development Center
FEMA	Federal Emergency Management Agency	**SCPDC**	South Central Planning and Development Commission
GLPC	Greater Lafourche Port Commission	**SLEC**	South Louisiana Economic Council
GOMP	Gulf of Mexico Program	**TEDA**	Terrebonne Economic Development Authority
LASAFE	Louisiana's Strategic Adaptations for Future Environments	**TLCD**	Terrebonne Levee and Conservation District
LDAF	Louisiana Department of Agriculture and Forestry	**USACE**	U.S. Army Corps of Engineers
LDCRT	Louisiana Department of Culture, Recreation, and Tourism	**USCG**	U.S. Coast Guard
LDEQ	Louisiana Department of Environmental Quality	**USDA**	U.S. Department of Agriculture
LDH	Louisiana Department of Health	**USFWS**	U.S. Fish and Wildlife Service
LDNR	Louisiana Department of Natural Resources	**USGS**	U.S. Geological Survey
LDOE	Louisiana Department of Education	**USNPS**	U.S. National Park Service
LDWF	Louisiana Department of Wildlife and Fisheries		

Step 9: Preparing and Implementing an Action Plan

BTNEP worked with the Water Institute to create an adaptation action for the risks that they chose to mitigate. The adaptation action outlines specific information about the risks addressed, parties responsible, next steps, and reporting frequency.

ADAPTATION ACTION: Reduction of Impacts from Invasive Species

The “Reduction of Impacts from Invasive Species,” titled EM-16 in the 2018 BTNEP CCMP (Table 3), is the action that BTNEP has chosen to lead responsibility for. To protect native organisms and resources, BTNEP will take actions to prevent and control the proliferation of invasive species. This action thus addresses 2 (of the 20) most important climate change risks facing the Barataria-Terrebonne estuary. The supporting parties listed have been previously identified in the 2018 CCMP, their participation was confirmed during the final surveying and workshopping process with BTNEP. BTNEP has also expressed the need to add one more supporting party to this Action Plan, the Governor’s Restore Louisiana Task Force.

Risk(s) addressed:

- Warmer air temperatures will result in changes in plant and animal communities with increased numbers of invasive species
- Warmer waters will result in an increase in abundance of invasive aquatic plants and animals

Responsible party(ies):

BTNEP will be supported by the following agencies: USDA Noxious Weed List, the Animal and Plant Health Inspection Service of the USDA, the USGS’s Nonindigenous Aquatic Species website, USGS Wetland and Aquatic Research Center in Louisiana, the Federal Native Plant Conservation Committee, the USACE’s Aquatic Growth Control Unit, USFWS’s invasive species program, NOAA’s invasive species program, LDAF, LDWF Aquatic Invasive Species Council, LSU Cooperative Extension Service, CWPPRA’s coastwide nutria control program, and the Governor’s Restore Louisiana Task Force.

Next steps:

BTNEP will be responsible for compiling summary reports on efforts to prevent and control the negative impacts of invasive species in the Barataria-Terrebonne estuary. These summary reports may include primary data, project updates, project results, or information synthesized from the work of the supporting agencies on this action item. Actions will focus both on the most serious invasive plant and animal species, and potential or emerging invasive plant and animal species. BTNEP will engage with scientists, educators, and the public to implement the following next steps:

- Use strategically placed PSA’s and signage to educate the public about the impacts of invasives and how to take action. Educational content may include the identification of current and potential invasives, distinguishing invasives from non-invasives, and who to report information to.
- Encourage legislation that can prevent the import of invasive species and help control the spread of invasive species.
- Develop projects that create markets around harvesting invasive species, such as using

bounties.

- Encourage data collection and education on controlling, preventing, and monitoring invasive species through a grant program.

Reporting frequency:

Updates on the progress of the "Reduction of Impacts from Invasive Species" action will take place annually in the form of a presentation during a BTNEP Management Conference meeting. The presentation will cover an annual review of all invasive species related actions, including "highlights [about] species of most concern, species that are currently being targeted by research, and species that are most likely to be invasive in the future" (Barataria-Terrebonne National Estuary Program, 2018).

In addition to the adaptation action above, there are 8 additional climate change risks that BTNEP will play a supporting role in addressing (Table 5). While BTNEP chose to transfer these risks, they are actively involved in supporting the implementation of these risks through 11 different CCMP Action Plans. Brief descriptions of the CCMP Action Plans are included in Table 3.

Table 5. BTNEP's Supporting Role in 8 of the Transferred Risks

Climate Change risk	**CCMP Action Plans that include BTNEP as a supporting organization**
Sea level rise will result in increases in salinity levels, followed by worsening of the symptoms of eutrophication, which include hypoxia and harmful algal blooms.	**EM-12** Improvement of Water Quality Through Stormwater Management; **EM-14** Assessment of Harmful Algal Blooms (HABs)
Warmer waters will result in an increase in fish and marine outmigration or die off due to hypoxia and harmful algal blooms.	**EM-12** and **EM-14**
Warmer waters will result in an alteration in the distribution of fish and shellfish stocks which will decrease the stability of fishermen's' livelihoods.	**PE-3** Seafood Promotion, Technology, and Marketing
Warmer waters will result in fishery harvesters having to adapt their practices due to changes in habitat for recreational and commercially important species.	**PE-3**
Sea level rise will result in the loss of ecosystem services associated with barrier islands and wetland areas (storm damage reduction, nature-based tourism, support for agriculture and aquaculture, and carbon sequestration).	**PE-1** Place Based Benefits of the Barataria-Terrebonne Estuary System; **PE-2** Scientific Literacy on Water; **PE-5** Climate Change as an Economic Driver
Increased storminess will result in frequent flooding in areas with inadequate stormwater infrastructure.	**EM-13** Urban Green Spaces
Warmer waters will result in an increase in the intensity of hurricane events and an increase in the frequency of Category 4 and 5 storms.	**CP-2** Emergency Response, Recovery, and Resiliency
Sea level rise will result in an increase in the concentration of microbes, which will lead to an increased likelihood of disease transmission for humans (from consuming infected seafood or from wound exposure in marine environments).	**EM-8.** Pollutant Identification and Assessment; **EM-17.** Improvement of Water Quality through the Reduction of Inshore and Marine Debris; **EM-18.** Protection of Drinking Water Sources

Step 10: Monitoring and Review of Action Plan Implementation

BTNEP's Climate Change Adaptation Plan outlines the responsible parties and action plans that will address each of the 20 climate change risks. BTNEP will provide an update on the 20 climate change risks and associated actions before the next CCMP revision. In the meantime, BTNEP will re-visit the Climate Change Adaptation Plan when a mitigating action is implemented; new information emerges about transferred, accepted, or avoided risks; or when climate change risks change (U.S. Environmental Protection Agency, 2014).

Table 3 serves as a template for revisiting each of the CCMP Action Plans that are associated with climate change adaptation. Many of the CCMP Action Plans have their own unique report-out requirements (Barataria-Terrebonne National Estuary Program, 2018). When revisiting all actions, BTNEP's primary responsibility will be to document any updates on their "Reduction of Impacts from Invasive Species" plan (outlined in Step 9) and their supporting role action items (Table 2, Table 4).

On an annual basis, the BTNEP Management Conference will be able to review and comment on the climate change risks and associated actions. Management conference members who are leading or supporting agencies on any of the Action Plans will provide any updates on their agency's progress on a particular action item.

"BTNEP supports conservation efforts that increase biodiversity." Image: Barataria-Terrebonne National Estuary Program, 2018

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Image: The Water Institute of the Gulf

APPENDIX

Potential Climate Change Risks Assessed in this Research

Table 6. Warmer Summers

Warmer Summers in the Barataria-Terrebonne Estuarine System Will Result in…	
Risks to Plants and Wildlife	Increased plant respiration, increased water stress, and reduced productivity.
	More stressed native species which allow for an increase likelihood of establishment of invasive species.
	A change in male/female ratio due to temperature-dependent sex determination of certain nesting reptiles (e.g. sea turtles and terrapins).
	An increased death of fishes, crustaceans, and amphibians as they exceed their biological limits for temperature and dissolved oxygen needs.
	Increased outbreaks of disease impacting wildlife.
Risks to Ecosystems	Decreased riverine flow from increase human usage and evaporation, less sediment delivered to coastal wetlands and beaches.
	More intense storms and hurricane events.
	An increase in evapotranspiration rates (the rate at which water evaporates into the air) which will lead to a decrease riverine flow or water levels.
	An increase in eutrophication (excess nutrients in water) and hypoxia (low oxygen) in estuarine bodies of water.
	A higher human demand for freshwater leading to a reduction in surface and belowground water volume.
	An increase of pollutants and aquatic debris from an increase in recreational activities.
	An increase in migration of commercially or recreationally important species.
	Overwhelmed local governments that will have to deal with the complexity of multiple adaptation demands.
	An increase in human demand for energy, leading to an increase in CO2 discharge from power plants.
	An increase in stopover of migratory birds.
	More harmful algal growth.

Risks to Humans	Decreased agricultural yields.
	An increase in evapotranspiration within the watershed, which will result in an increase in surface water pollutant concentrations.
	Increased outbreaks of diseases affecting human health.
	An increase in harmful algal bloom events, negatively affecting local tourism and businesses.
	An increase in heat strokes and dehydration, in addition to an increase in heart and lung diseases from ground level ozone.
	A longer summer season, which will result in an increase in visitors and residents who will strain wastewater, transportation, and recreational infrastructure.

Table 7. Warmer Waters

Warmer Winters in the Barataria-Terrebonne Estuarine System Will Result in…	
Risks to Plants and Wildlife	An increase in disease prevalence and survival in overwintering populations.
	A shift in the reproductive cycles of aquatic and terrestrial organisms.
	Animals using more winter reserves to stay active when normally dormant which could decrease survival rates later on in the year.
	Changes in pattern and timing of migratory birds.
	A change in fresh and marine species composition and an increase in physiological stress in species.
	Less dissolved oxygen due to increased water temperature.
	Increase in damage caused by pests such as the southern pine beetle.
Risks to Ecosystems	Seasonal residents staying longer, which will contribute to a higher volume of sewage and other waste.
	An increased use of insecticides due to higher overwintering survival rates of pests.
	Expansion of tropical species northward like black mangroves into salt marshes.
	Increased likelihood of invasive species to become established.
	More events of eutrophication and hypoxia in estuarine bodies of water.

Risks to Humans	An increase in the activity and abundance of invasive species, causing an increase in the costs to manage invasive species.
	A longer growing season and a higher tree mortality from pests, causing a greater risk for forest fires.
	An increase in the survival of disease carrying pests (e.g. mosquitoes and ticks).
	A higher tree mortality caused by pests, resulting in lower lumber yields and less revenue from lumber.
	A disruption to growing seasons, which could make crops more vulnerable to cold snaps.

Table 8. Increasing Droughts

Increasing Droughts in the Barataria-Terrebonne Estuarine system will result in…	
Risks to Plants and Wildlife	Habitat loss, which will change species composition and range, including predator/prey population sizes.
	Smaller water bodies and perennial streams drying up, which will lead to loss of dependent species.
	Increased salinity of the estuary, affecting the distribution of species.
	Reduced river flows, an increase in the frequency and duration of saltwater intrusion, and subsequent shifts in plant communities and associated food webs.
	Higher soil salinity resulting in changes in vegetation composition or change from vegetated to barren areas.
	Increased stress on aquatic and terrestrial organisms, which will require changes in management and monitoring plans.

Risks to Ecosystems	An increase in nutrient runoff due to higher uses of irrigation in the residential and industrial sectors.
	Vegetation diebacks and subsequent nutrient pollution.
	A decrease in nutrient uptake creating more residual nutrients that can become mobile during flash storms.
	Decreased water flow, which will lead to higher concentrations of nutrients and pollutants in receiving waters.
	Water conservation measures that may take precedence over restoration projects.
	A decrease in riverine flow, which may starve coastal marshes and barrier islands of needed sediment.
	More stressed vegetation, which will decrease the success rate of restoration projects.
	An increase in soil loss from wind-driven erosion.
	An increase in recreational activities that involve water bodies which will cause an increase in pollutants and aquatic debris.
Risks to Humans	A decrease in crop yields due to water stress.
	Decreases in rainfall for irrigation crops, which will lower surface and subsurface water tables.
	An accumulation of toxic particulate matter, which will more easily distributed during rain events that follow droughts.
	An increase in wildfire risks.
	A reduction in riverine flow and an increase in sediment deposition, which will negatively affect shipping traffic.
	More water restrictions for conservation efforts, which will lead to increased tension between resource managers and local communities.
	A lower water table, which will cause an increase in subsidence along the coastline.

Table 9. Increasing Storminess

Increasing Storminess in the Barataria-Terrebonne Estuarine system will result in…	
Risks to Plants and Wildlife	Extended periods of high rain volume which will alter salinity levels and impact marine species.
	Increased erosion and resuspension of sediment which will lead to increased turbidity and decreased light penetration in the water column for phytoplankton.
	Loss of habitat due to wind- and water induced erosion.
	Increased physiological stress to freshwater plants and animals due to saline intrusion from storm surge.
	Increased turbidity and decreased light penetration available to submerged aquatic vegetation.
	Disruption to migration patterns due to shoreline armoring to protect properties.
Risks to Ecosystems	High volume rain events which can lead to increased nutrient and sediment loading.
	The resuspension of contaminated sediments.
	More washovers, which will lead nearshore habitats to change or shift.
	Higher rates of riverbank, streambed, and shoreline erosion.
	More shoreline hardening to reduce shoreline erosion.
	A hinderance to monitoring field work.
	Higher maintenance costs of existing and restored shoreline projects.
	The shoaling of navigable areas, more frequent dredging, and a reduction in state funds for restoration projects.
	The introduction of aquatic invasive species to new areas due to flooding.
	Increase likelihood of barrier island breaches, which can disrupt barrier island restoration efforts.

Risks to Humans	Frequent flooding in areas with inadequate stormwater infrastructure.
	Higher costs for managing stormwater runoff and a reduction in local government funds.
	Overwhelmed septic tanks, drain fields, and municipal wastewater treatment plants.
	Storm damage to structures, facilities, and vehicles, which will release contaminated fluids to wash into the bays
	The loss of shorefront properties due to higher rates of erosion.
	The loss of shorefront properties and properties in low lying areas which may not be replaced.
	Higher insurance rates, forcing residents to be uninsured.
	Negative impacts on local tourism and businesses due to closure of recreational facilities caused by bad weather.
	An increase in the spread of aquatic weeds which may obstruct waterways.
	The disruption of shipping traffic, which will affect the transport of goods and services.
	Increase in crop loss due to severe weather.
	Increased shutdowns of nearshore/offshore oil and gas production, negatively impacting local, state, and federal economies.

Table 10. Sea Level Rise

Sea Level Rise in the Barataria-Terrebonne Estuarine system will result in…	
Risks to Plants and Wildlife	Loss of habitat for fish, birds, and plants.
	A reduction in nesting area suitable for sea turtles, aquatic birds, and other marine creatures.
	Change in species distribution and range due to intrusion of sea water into freshwater systems.
	A loss of coastal and maritime forest and adjacent freshwater habitat.
	Areas of brackish marsh transitioning to salt marshes
	Inability of species to migrate further inland due to physical barriers from flood mitigation structures.

Risks to Ecosystems	Changes in current and circulation patterns of estuary lagoons.
	Land loss which will reduce the amount of nutrients removed via natural processes.
	A change in species distributions, such as the inland migration of more saline tolerant species.
	Wetland drowning and increased shoreline armoring, causing limited landward retreat of the wetlands.
	Wetland loss and their associated ecosystem functions and services.
	Incursions of water upland that could flood toxic containment sites.
	More washovers, which will cause nearshore habitats to change or shift.
	Loss of barrier island, which will no longer providing protection to the coast line.
	An increase in shoreline armoring.
	Community relocation to land that was previously for wildlife habitat.
	Increased pollution to surrounding areas from abandoned infrastructures (e.g. ghost towns) from community relocations.
Risks to humans	A decrease in the effectiveness of existing flood mitigation structures.
	The exacerbation of stormwater flooding.
	Decreased access to water infrastructures (boat ramps, marinas, parking lot, etc.).
	Significant damage to existing infrastructure.
	The loss of shorefront properties and properties in low lying areas which may not be replaced.
	Increase in navigation risks, as low-lying areas and any associated infrastructure become submerged
	Costly building regulations.
	An increase in coastal flooding and an increase in insurance costs to unaffordable amounts which will force residents to abandon or sell their coastal properties.
	Urban areas becoming overwhelmed by rising water resulting in community relocations.
	Higher water tables which will inundate septic drain fields.
	Sewage overflow which may lead to more toxic contaminants.
	An increase in aquifer salinity.
	Salt contamination in agricultural soils.
	A loss of habitat for recreational and commercially important species, which will reduce fishery harvests.

Table 11. Warmer Waters

Warmer Waters in the Barataria-Terrebonne Estuarine system will result in…	
Risks to Plants and Wildlife	Longer algal bloom seasons, including harmful algal blooms, which will cause a large swing in dissolved oxygen and an increase in fish/marine die off.
	An increase of diseases and parasites which will impact the health of aquatic organisms.
	Changes in aquatic species composition, breeding, and range.
	Negative impacts on migratory patterns of animals.
	The stunting of fish growth.
	Reduction of dissolved oxygen available to aquatic organisms.
	Increase physiological stress as aquatic organisms reach their thermal limits.
	Changes to the sex of sea turtles, diamondback terrapins, and other reptiles due to sand-temperature-dependent sex determination in nests.
Risks to Ecosystems	An increase in phosphorus release from sediment which could lead to algal blooms.
	Local extinction of aquatic species in confined areas (e.g. lakes or ponds) that reached their thermal limits and cannot migrate to new habitats.
	An increase in invasive aquatic species.
	Additional stressors on aquatic resources, which will require changes in the management and monitoring plans for fisheries and will reduce harvesting.
	An increase in microalgae, harmful algal blooms, and bacteria, which will require a change in management and monitoring frequency.
Risks to humans	An increase in the concentration of diseases and pathogens, which can impact human health.
	Higher bacterial and pathogen loads in commercially important waters which may lead to more regulations and shorter harvesting seasons for shellfish.
	An increased likelihood of disease transmission from consuming infected seafood or from wound exposure in marine environments.
	An alteration in the distribution of fish stocks which will pose serious risks to fishermen livelihoods.
	Algal growth which will cause recreational water uses (fishing, swimming, crabbing, etc.) to be less attractive.
	An increase in the intensity of storms, hurricanes, and El Niño events.

Table 12. Ocean Acidification

Ocean Acidification in the Barataria-Terrebonne Estuarine system will result in…	
Risks to Plants and Wildlife	More corrosive waters, which will impact the shell development of bivalves and exoskeletons of crustaceans.
	Negative impacts on fish reproduction and early life stages.
	Alter fish behavior, bone formation, and growth.
	Increased physiological stress and death of aquatic organisms due to difficulties accessing dissolved oxygen as water become more acidic.
	Changes to survival, growth, and physiology of calcium carbonate structured plankton can have impacts throughout the food web.
Risks to Ecosystems	Heavy metals (e.g. cadmium, lead, copper) to dissolve more easily.
	More corrosive waters may cause toxic contaminants to leach out of stable/inert state.
	Increasing costs to monitor and manage affected species.
	Decreased capacity of ocean to absorb CO2 as it becomes more acidic.
Risks to Humans	A reduction in aquaculture activities and a reduction in investments for commercially important species (e.g. oyster, shrimps, crabs, etc.).
	A reduction in harvests of commercially important species (e.g. oysters, shrimps, crabs, etc.) which may reduce income and job security for workers.
	The ocean being less effective in moderating climate changes, causing an increase in the impacts of climate change.

Image: The Water Institute of the Gulf

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