3.0 CITY OF DARIEN

Located at the mouth of the Altamaha River, the city of Darien has a vibrant history. Now a small, quiet town of 1,975 people, Darien was once a major port along Georgia's coast. Founded in 1736 by General James Oglethorpe, it is Georgia's second oldest planned community.

According to the 2010 Census, there are a total of 798 households in Darien. Of these, 248, or 31%, have children under the age of 18 and 63.4% are owner occupied. Although small, the population has steadily grown in recent decades with a 13% increase from 2000 to 2010.

A number of the city's population characteristics present an economic development challenge. According to the 2011 American Community Survey (ACS) Five-Year Estimates, only 15% of the population over the age of 25 has earned a bachelor's degree or higher as opposed with 27.5% statewide. For the population aged 18-24, the numbers drop significantly and only 43.4% have graduated from high school. The median household income in Darien is $34,098, and the unemployment rate in McIntosh County in July 2013 was 10.4%. This was significantly higher than the national rate of 7.4% at the same point in time (Bureau of Labor Statistics).

As a small, rural community, Darien has a much less diverse economy than a large city like Savannah, which may lead to the impacts of SLR being felt more acutely within the city's key industries. This report analyzes

three areas of the local economy that would most likely be affected by SLR: commercial fishing, tourism & small businesses, and residential real estate.

Given the differences between Darien's economy and the economic activity at the Port of Savannah, it was important to approach the economic impact analysis in a different way. For Darien, it was essential to gain a thorough understanding of how these smaller industries operated in order to draw a connection between the environmental impact of SLR and the daily life of the workers and residents of Darien. The *Blueprints* team found that the most severe economic impacts would likely be felt by the fishing industry and to a lesser extent tourism and small business. The least affected was industry was residential real estate. The research focuses on each of these sectors accordingly.

3.1 PREVIOUS STUDIO RESULTS FOR THE CITY OF DARIEN

In Fall 2012, the Georgia Conservancy sponsored a graduate studio from Georgia Tech's City and Regional Planning program, led by Dr. Larry Keating and Dana Habeeb, to study communities along Georgia's coast and investigate the potential impacts of SLR, specifically focusing on vulnerable populations and communities. The study area of this report included Chatham County, Liberty County, and McIntosh County. The research of the studio provided the building blocks for the current study of the economic impacts of SLR in Darien in McIntosh County, and the Port of Savannah in Chatham County.

The previous report analyzed the impact of SLR on the Georgia coast over a 100 year period from 2010 to 2110, with the assumption that current economic conditions would continue over the study period. The Georgia Conservancy, Keating and Habeeb used several different forms of modeling to determine the effects of SLR along the Georgia coast. First, they used the Skidaway Institute of Oceanography's hydro digital elevation bathtub model, estimating effects of a one meter rise in sea level on total land area. The researchers acknowledge that this model did not account for land cover changes such as wetland migration, and likely overestimates wetland losses.

In order to estimate the potential damage to physical structures, the Georgia Conservancy *Blueprints team* used the Federal Emergency Management Agency's HAZUS data from the year 2000. The HAZUS data set divides buildings into seven broad categories: residential, commercial, industrial, agricultural, religious, education, and government. Within each category, the data set provides the number of existing buildings that would be impacted by SLR and an estimation of the structures' replacement value.

According to the previous studio's results, McIntosh County experienced the largest threat of flooding due to SLR among the studied counties with nearly 20% of residential land predicted to be inundated. Most of the impacted land in the county is concentrated in Darien.

Table 3.25 and Table 3.26 displays these results for the City of Darien.

According to the results from the Bathtub Model run by the fall 2012 *Blueprints team*, 29% of all land in the city of Darien is projected to be inundated due to SLR over the next 100 years. The majority of this land is currently classified as Park/Recreation/Conservation area. The residential land will experience the second most impacted with 20.37% inundation. The HAZUS model predicts that 75 residential buildings will be impacted, which accounts for 6.57% of all residential buildings in the city. Four commercial buildings and four industrial buildings are also expected to be impacted.

Land Use	Total Acreage	Percent Inundated
Agriculture/ Forestry	61.62	0.49%
Commercial	79.17	6.43%
Industrial	5.29	0.00%
Parks/ Recreation/ Conservation	313.15	87.63%
Public/ Institutional	45.83	0.00%
Residential	871.6	20.37%
Transportation/ Communication/ Utilities	221.95	0.50%
Undeveloped/Vacant	128.53	4.00%
Total	1,727	29.09%

Table 3.25: Land Use - Total Acreage and Percent Inundation in Darien. Source: Georgia Conservancy, 2012.

	Total Buildings	Inundated Buildings	Percent Inundated	Total Building Replacement Value	Inundated Building Replacement Value	Percent Inundated Value
Residential	1,141	75	6.57%	$101,599	$10,003	9.85%
Commercial	55	4	7.09%	$65,190	$21,448	32.90%
Industrial	12	4	32.42%	$7,508	$2,983	39.73%
Agriculture	4	1	35.00%	$1,032	$408	39.53%
Religion	8	2	21.25%	$10,502	$5,253	50.02%
Government	8	2	23.75%	$5,578	$906	16.24%
Education	4	0	0.00%	$4,342	$0	0.00%
TOTAL	1,232	88	7.13%	$195,751	$41,001	20.95%

Table 3.26: HAZUS - Number of Inundated Buildings and Replacement Value in Darien (Note: Replacement Values are x $1,000)
*Calculations based on Skidaway Institute and 2000 HAZUS data
Source: Georgia Conservancy, 2012.

The team then conducted a Temporal Analysis of Darien (Found in Georgia Conservancy Appendix 2012). Some 62.9 % of Darien's total area of 21.2 miles will experience inundation. This inundation is particularly pronounced in the 15.8 square miles of wetland area with 85.9% or 13.6 square miles of inundation. Of the 1.8 acres of developed areas, 20.9% and seven miles of primary roads are projected to be inundated.

As a one of the Georgia coast's most historically significant places, Darien could see impacts to some of its treasured historic sites as well. Loss of these assets are difficult to quantify, but the fall 2012 *Blueprints* studio noted that historic structures like Fort King George in Darien, the nearby Hog Hammock Historic District on Sapelo Island, and the Sapelo Island Lighthouse are difficult to replace due to their cultural significance.

3.2 LOCAL INDUSTRIES IN DARIEN

COMMERCIAL FISHING

Commercial shrimping and fishing have long played a significant role in both the economic and cultural life of Darien (Coastal Georgia Regional Development Center 2007). Following the collapse of the timber industry

from over-cutting in the 1920s, Darien's population turned to commercial seafood as a means of renewing growth in the city (Sullivan 2002). By the early 1960s, McIntosh County had the largest shrimping fleet in Georgia and boasted several shrimp and oyster packing houses in Darien (Sullivan 2002). At its peak, local fisherman report that Darien was home to some 60 shrimping vessels. In homage to the importance of this industry, Darien, since 1968, has hosted the Annual Blessing of the Fleet Ceremony to celebrate the tradition and promote Georgia shrimping.

This *Blueprints studio* analysis of the fishing industry in Darien is focused on the three largest fisheries (by tonnage) shrimp, crab and jellyfish (Graitcer 2012). A key support element for each of these industries is the wetland ecosystem found in the marshland of Darien. Already an area of concern due to the increasing development pressure on areas of deep water access and scenic marshland views which may alter the functioning of coastal marshland ecosystems, the threat of SLR may compound these ecological impacts (Coastal Georgia Regional Development Center 2007). A Georgia Department of Natural Resources report estimates that since the late 1700s, more than 1.5 million acres of wetland have been altered. The State of Georgia now contains some 429,294 acres of these, nearly half of which (192,099 acres) are contained within McIntosh County, including 324 acres of wetlands within the developable area of Darien (Coastal Georgia Regional Development Center 2007).[2] Including the recently annexed Altamaha Wildlife Management area, which is primarily marshland, 68% of the land area of Darien is made up of coastal wetlands (Ecological Planning Group 2008).

In fact, the Darien waterfront provides both scenic views of the marshland and docking space for local shrimping vessels, which, in turn, rely heavily on shrimp populations which mature in the surrounding wetlands. These tidal wetlands serve an important role not only in providing vital habitat and feeding ground for numerous fisheries and aquatic species, but also "provide a storm surge buffer, prevent erosion, disseminate pollutants, and provide economic benefits to local and state governments" (Ecological Planning
Group 2008).

The focus of this section is to see how SLR will affect the fisheries through the wetlands that play a crucial role as habitat, food source and nursery habitat for these species, as well as the direct impact of SLR on these species themselves. This research will lead to recommendations as to how the industry will be affected and how the people of that industry can best adapt to the changing conditions of SLR, in order to maintain a viable economy in Darien, consistent with its character.

SALINITY AND SLR

Salinity level, which refers to the concentration of salt in water, is an important feature of estuarine and wetland habitat. While salinity in open ocean remains notably constant at around 35‰ (parts per thousand), the salinity of estuaries and wetlands can vary significantly depending on the location within the estuary, the amount of fresh water flowing into the estuary, and the tides (NOAA). Though salinity levels are typically highest where the mouth of the river meets the ocean and lower upstream, salinity can vary as a result of the tidal cycle, with lower salinities in the spring due to melting snow and increased rainfall and higher in the summer as increased temperatures result in a greater amount of evaporation (NOAA). In particular, salinity can influence the amount of oxygen that is dissolved in water, with solubility falling as salinity levels rise (NOAA). As a result, salinity levels beyond a suitable range for species which live and breed in the wetland areas, "will negatively affect their growth and reproduction, and ultimately, their survival" (NOAA).

It is difficult to overstate the impact that salinity can have on marine species: "Salinity may be the most important factor affecting the distribution of estuarine organisms. It is an essential element in determining estuarine habitat and directly affects the distribution, abundance and composition of biological resources" (NOAA). A 2009 study of Georgia estuaries by Wiçski, Guo, Craft, and Pennings found that across salinity spectrum, ecosystem function in tidal wetlands change, and the richness of plant species diversity decreases by as much as five times with increasing salinity (Wiçski et. al 2010). The study found that the biomass, height, and nutrient retention of aquatic plant life near the water's edge decreases from tidal fresh to tidal salt marshes (Wiçski et. al 2010). These aquatic plants, called macrophytes, provide protection, oxygen, and a food source to fish and aquatic invertebrates, including shrimp and crab, in the tidal marsh ecosystems. The study's authors go on to suggest that SLR could trigger changes in plant distribution patterns with cascading impacts on wetland functions and services (Wiçski et. al 2010).

As a transitional area between land and sea, salt marshes are especially vulnerable to SLR and the resultant salinity changes (Simas et. al 2001). A 1999 University of Georgia study found that, over the period from 1973 to 1992, surface salinity samples taken from the Savannah, Ogeechee, Altamaha, Satilla, and St. Mary's River estuaries suggested a statistically significant decrease in discharge and increase in salinity in the Satilla and Savannah River estuaries. They also found a marginally significant decrease in discharge and increase in salinity and flushing time for the Altamaha River (Alber & Sheldon 1999). This study further cites "anecdotal reports that historic changes in salinity have already had an impact on the distribution of plants (e.g. wild rice) and animals (e.g. crabs) in these systems" (Alber & Sheldon 1999). While the study notes that the data collected could not distinguish the exact cause of these changes (be it changes in geomorphology, changes in local runoff characteristics, or direct groundwater input), it should not be discounted that the "observed increases in salinity could be the result of large-scale changes such as sea level rise or short-term increases embedded in a larger climatological cycle of rainfall and drought" (Alber & Sheldon 1999).

In the body of literature surrounding SLR, there is broad agreement that "sea-level rise will alter hydrologic patterns, resulting in changes in salinity intrusion dynamics along coastal rivers" (Water Research Foundation 2012). The variability of salinity is influenced by a number of factors, but especially stream flow, which is contingent on precipitation and anthropogenic alteration of freshwater flow, and water-level conditions (Water Research Foundation 2012). These variations in salinity in turn, can greatly impact the characteristics of wetlands; a 2004 study by Higinbotham et al. concluded that marsh-type is more highly correlated with salinity than elevation when fresh-water flow is significant (Higinbotham et. al 2004). As a number of the current studies on the impacts of SLR are focused more broadly on predicting the impacts of climate change, it is common to calculate both for SLR and altered precipitation patterns.[3]

A 2009 study conducted by Craft et al. explored the susceptibility of the tidal marsh ecosystem to accelerated SLR and concluded: "Model simulations using the Intergovernmental Panel on Climate Change (IPCC) mean and maximum estimates of sea-level rise for the year 2100 suggest that salt marshes will decline in area by 20% and 45%, respectively. The area of tidal freshwater marshes will increase by 2% under the IPCC mean scenario, but will decline by 39% under the maximum scenario" (Craft et. al 2009). The findings further suggest "that tidal marshes at the lower and upper salinity ranges, and their attendant delivery of ecosystem services, will be most affected by accelerated sea level rise, unless geomorphic

conditions (i.e. gradual increase in elevation) enable tidal freshwater marshes to migrate inland, or vertical accretion of salt marshes to increase, to compensate for accelerated sea level rise" (Craft et. al 2009). Of specific relevance to this studio, for the Altamaha River in particular, "the model predicts a large decline in area of tidal freshwater marsh (–38%) and swamp (–24%), a smaller decline of salt marsh (–8%), and a small increase in brackish marsh habitat (+4%)" (Craft et. al 2009).

The distinction in these categories of marsh are important because the "results suggest that salt, brackish, and tidal freshwater marshes of the Georgia coast will respond differently to a 52-cm increase in SLR" and as (noted before) salinity ranges have a profound effect on the distribution of estuarine organisms (Craft et. al 2009). The decrease in the quantity of saltmarsh, attributed to submergence and replacement by tidal flats and estuarine open water may be particularly detrimental to shrimp and crab populations (Craft et. al 2009). The following sections examine the impact that salinity may have on various species, and analyzes the results of a SLAMM (Sea-Level Affecting Marshes Model) model run by the South Atlantic Migratory Bird Initiative (SAMBI), similar to that run in the Craft study in order to understand the progression of this marshland loss over time.

SHRIMP FISHERY

Darien's largest commercial fishery is shrimping, with harvests of both brown shrimp[4] and white shrimp.[5] Each year, the DNR Commissioner opens offshore waters to commercial seafood shrimping on May 15 and it remains open until December 31, provided that shrimp counts are 45 or fewer per pound (with heads on) (Georgia Department of Natural Resources 2013).[6] The legal hours for the commercial harvest of shrimp begin 30 minutes before official sunrise and extend

Figure 3.1: Tidal Marsh outside Darien

to 30 minutes after official sunset (Georgia DNR 2013). The early part of the season (May and June) is dominated by the catching of white shrimp, with some commercial vessels going as far as North Carolina. As the season draws later, the shrimpers shift their catch to brown shrimp, which become available from June to August, before the white shrimp return toward the end of the season in December.[7] Wild caught shrimp generate nearly $12 million of revenue annually across the state (McLeod 2013).

The shrimp are caught using a method called trawling, where a boat (known as a trawler) trails one or more large nets (sometimes as wide as 200 feet) across the seafloor typically within five miles of the shore. The trawlers are operated by a captain and one or two crew members, depending on the size of the vessel. The shrimping crews go out on trips from five to seven days at a time (according to the vessel's ability to carry enough fuel and ice), and in the past have brought in between 600-800 pounds (6 to 8 boxes) of shrimp at a time. In turn, these shrimp are currently sold for around $6.50 a pound and are distributed across a wide range of geographic locations.[8]

Median salary for commercial fisherman in the United States is $25,590 (Bureau of Labor Statistics 2013). In the last several years, Darien's shrimpers have suffered greatly. In 2013, shrimpers anticipated increased profits as the price per pound climbed more than a dollar due to import shortages.[9] However, conversations with commercial fisherman indicate that not only are they harvesting fewer shrimp, but the shrimp they do bring in are much smaller (Landers 2013). This season, local shrimpers in Darien have only been able to harvest 200-400 lbs (2 - 4 boxes), taking a significant toll on their profits after expenses. With gas prices rising to $3.50 per gallon and boats consuming in excess of 150 to 200 gallons per trip, after paying crew members for a week's worth of work, repairing damaged nets, and purchasing ice to store the shrimp, expenses easily can climb into the thousands. For a larger shrimper, a trip may cost almost $4,000. As a result, a once bustling shrimping industry in Darien has seen a fleet of almost 60 boats dwindle to between 20 and 30.[10] This trend is consistent with a state wide exodus from the industry which has seen the number of fishing boat licenses issued each year for shrimping fall from around 2,000 in 1979 to about 165 in 2013 (Landers 2013).

The most recent wave of declining profits are closely linked with steep declines in shrimp populations, driven by a devastating disease known as Black Gill. This was identified by multiple shrimpers interviewed in Darien as the biggest obstacle to good fishing. Black Gill is caused by a type of parasite, called a ciliate, that "attaches and penetrates the gills in the trophont stage" of the shrimp (South Carolina Department of Natural Resources 2012). According to the South Carolina Department of Natural Resources, the disease "impairs respiration, thus reducing the shrimp's endurance. This may ... make the shrimp more vulnerable to predators or temperature extremes" (SCDNR 2012). Black Gill starts in August and usually subsides around December. In 2013, nearly 90% of shrimp caught in some trawls have been infected (McLeod 2013). In September, shrimpers in South Carolina caught 44,000 pounds of shrimp, just 6% of the 750,000 pounds that they had caught in the same month a year earlier (McLeod 2013). The situation is only slightly improved in Georgia where in August, September, and October shrimpers have pulled in less than half of their average haul (McLeod 2013).

Between 1998 and 2002 the Southeast experienced record breaking drought and saw increasing incidence of saltwater intrusion along the Georgia and South Carolina coasts, causing some to speculate that high salinity may be to blame (Water Research Foundation 2012). With record high rainfall and frequency of the parasite only climbing, wildlife experts have begun to explore the possibility that too much change in

water salinity upset the balance of fresh and salt waters, stressing shrimp, and leaving them vulnerable to the parasite (McLeod 2013). Local shrimpers also reported hearing from wildlife experts about a relationship between outbreaks of the disease and fluctuating salinity levels. Additional research is needed to understand this parasite's life cycle and the environmental factors causing its proliferation in some years but not others (Water Quality in Georgia 2006-2007 2008).

Complicating the understanding of the role of Black Gill is the fact that shrimp populations can undergo dynamic stock fluctuations from year to year. When temperatures drop to the low 40s, the cold can kill overwintering shrimp in the estuaries (Stepzinski 2011). White shrimp, being a subtropical species, tend to be more susceptible to large stock fluctuations than do brown shrimp populations (SCDNR 2012). While the larger white shrimp migrate as far as south as Cape Canaveral, Florida, most are caught before they are able to migrate back (SCDNR 2012). Thus, the primary spawning stock are smaller white shrimp that over-winter in the estuaries (SCDNR 2012). In December of 2010, DNR coast wide sampling of shrimp showed a population 11% larger than the long-term average (Stepzinski 2011). By February of the next year, following an especially cold winter in which temperatures dropped to lethal levels, coast wide sampling catches of shrimp were 95% below the average populations (Stepzinski 2011).

While the exact cause of this declining population, its relation to Black Gill, and the cause of Black Gill merit additional exploration, we are seeking to understand the role that SLR and the subsequent changes in salinity of the wetland nurseries may play in the industry's future. To this end, an understanding of the shrimp's reliance on estuaries and wetlands may prove helpful.

Howe, Wallace and Rikard offer this concise explanation of the panaeid shrimp life cycle:

> "The life cycles of penaeid shrimps include offshore spawning, oceanic larval development [as planktonic larvae], and migration into estuaries as postlarvae after being transported to coastal areas by surface ocean currents [where they remain for two to three months until they are about four inches]. The timing of postlarval shrimp movements into estuaries appears to be species specific. Brown..., pink..., and white ... shrimp are typically found in estuaries in greater abundance during the spring, winter, and summer, respectively. Once in the estuaries, rapid growth is followed by migration of subadults to the open ocean where their life cycles are completed" (Howe et al. 1999).

Within the estuaries, post larval shrimp migrate into the shallow waters at the upper ends of the saltmarsh tidal creeks (SCDNR 2012). The shrimp concentrate in the creek beds, traveling into the marsh grass to feed at high tide (SCDNR 2012). As they grow, smaller shrimp remain in creek beds feeding on plant and animal organic materials at the bottom, while larger juvenile shrimp move into the deeper creek waters (SCDNR 2012). The shrimp grow as much as 2.5 inches per month while in the estuaries, molting several times per week with decreasing frequency as they grow (SCDNR 2012). Upon reaching about 4 inches in length, shrimp gradually move towards higher salinity levels in the coastal rivers and ocean (SCDNR 2012). These coastal rivers allow for some additional growth while the shrimp move into the "lower reaches of sounds, bays, and river mouths," which serve as a "staging area" for population accumulation, prior to the final migration into ocean waters (SCDNR 2012). During periods of large populations, the shrimp will migrate into the ocean at lengths of four to five inches, but when stocks are small, they may remain in the estuaries until they are more than six inches (SCDNR2012). Once in the

open ocean, most shrimp will die before reaching nine months of age (SCDNR 2012).

A growing body of literature has begun to explore the impacts of salinity and temperature on shrimp growth, maturation, reproduction, and mortality. According to the South Carolina Department of Natural Resources, the "ideal nursery habitat has brackish water that is about 25 to 40 percent sea water [about 9 to 14‰ [11]] for white shrimp and 35 to 65 percent sea water [about 12 to 23‰] for brown shrimp," though they can survive in higher and lower salinity levels (SCDNR 2012). Beyond the size of the shrimp population that survived the previous season to spawn and water temperature, the most important factor influencing shrimp abundance is the salinity of the nursery habitat (SCDNR 2012). A 2001 study in France found mortality was higher for brown shrimp at 5‰ salinity than at higher salinities, females raised at 25‰ salinity started to become ovigerous (bearing eggs) after 32 days as oppose to 80 days for those females held at 15‰, brackish salinity (15‰) would delay ovarian development as opposed to higher salinities, and low salinities (5‰) inhibited maturation (Gelin et al. 2001). Similarly in a 2003 study, when a 4-week growth trial was conducted with juvenile brown shrimp at 2‰, 4‰, 8‰, and 12‰, shrimp maintained at 8‰ and 12‰ grew significantly more than shrimp maintained at 2‰ and 4‰ (Saoud & Davis 2003). One study by Wang and Chen explored the immune response of white shrimp[12] at differing salinity levels. When injected with Vibrio alginolyticus, a bacteria known to infect commercial farmed shrimp with devastating effects, mortality began to occur within six hours for shrimp held at 5‰ and 15‰ and was significantly higher than for shrimp held at 25‰ and 35‰ (Wang & Chen 2005). After four days, the total mortality was found to be the lowest at 25‰ and highest at 5‰ (Wang & Chen 2005). Further it was concluded that change in water salinity can trigger disease outbreak (Wang & Chen 2005).

There is however, still some debate in the literature. A 1996 study conducted by Zoula Zein-Eldin found that growth rate did not differ significantly among shrimp[13] held at 2, 5, 10, 25, or 40‰ (Zein-Eldin 1996). A study one year later, by Ponce-Palfox, Martinez-Palacios, and Ross, concluded that survival and growth rate of postlarvae white shrimp[14] were dependent not only on temperature and salinity, but also on the temperature-salinity interaction. The results showed that higher salinity had a negative correlation with growth and survival only at higher temperatures and salinity of 20‰ (the low salinity range of the study) appeared to have a negative impact on growth and survival at temperatures greater than 25˚C (Ponce-Palafox et al. 1997).

One final note on the shrimp fishery relates to the rapid rate of land development along the coastal southeastern United States, which has been a growing topic of concern for fisheries management. According to a study concerning grass shrimp[15] conducted by Porter et al., "adult grass shrimp abundance is depressed in urbanized estuary compared to pristine estuary (1997). In fact, in Murrells Inlet, South Carolina, streams adjacent to residential or commercial development contain the lowest density of grass shrimp, in some cases serving as near "estuarine deserts – stream reaches void of adult grass shrimp" (Porter et al. 1997). Though of a different species than the brown or white shrimp, these grass shrimp results suggest a potential environmental impacts on commercially fished shrimp species as well, or at the very least, an area worthy of further scientific exploration.

CRAB FISHERY

The second largest fishery in Darien is the blue crab fishery. The season for blue crabs in Georgia is year round, but most often the crabs are caught in the summer and early fall (Van Den Avyle 1984). Female crab carrying eggs, called sponge crabs, are common

Figure 3.2: Shrimp trawlers at Darien's port

from April until September and are protected from harvest by law (Whitaker 2010). While earlier stages of development, the zoea larval and megalopal, take place off shore, the megalopae begin a migration into the saltmarsh creeks (Whitaker 2010). Within the estuarine nursery habitat, the megalopae transforms into the juvenile crab (Sartwell 2009). The preferred habitat for blue crabs is "tidal salt marsh estuaries, typically with … moderate salinities" (Cooley 2003). This optimal range is between 20.1-31.1‰ for larval stage, and 22-28‰ salinity is required for "normal hatching of eggs and for normal development of zoeae."

Following the zoeae, megalops, and juvenile stages, however, the salinity range for adults is much wider so as to accomodate the high salinity ocean waters encountered in the later stages of its life cycle (Whitaker 2010). Young crabs thrive in years of increased freshwater in the system as it brings more nutrients while decreasing the salinity levels (Whitaker 2010). Water temperature is also essential factor for the development of crab, with optimal levels being found between 21-30 degrees Celsius (Van Den Avyle 1984).

The females migrate into the higher salinity levels of the mouth of the estuaries or ocean to spawn, reinitiating a cycle in which only about one of every one million eggs will survive to adulthood (Whitaker 2010). The majority of crabs stay within one estuarine system for their life and most live less than one year (Van Den Avyle 1984). Historically, Georgia's crabbers have experienced the consequences of changes occurring in the habitat of the blue crab. The most poignant example of this can be seen with the parasite, Hematodinium. In this

example, a drought in the state caused a 45-year average of 8.6 million pounds of crab a year in catch to fall to 1.8 million pounds. This parasite was not formerly unknown, but because of the crabs' needs for specific water conditions in terms of salinity the effect of the drought was severe:

> "During a drought, less fresh water comes down the state's rivers to mix with salt water that tides bring in from the Atlantic Ocean. This raises the salt content in coastal estuaries. And it is in water with this higher percentage of salt that Hermatodinium thrives and spreads from crab to crab. Lee and Frischer found a direct correlation between the state's recent drought and the prevalence of the disease in the state's blue crab population. They also cite data showing that during times of high river flow, when the percentage of salt in the estuaries is lower, blue crab landings historically have increased" (Science Daily 2003).

CANNONBALL JELLYFISH

Cannonball jellyfish make up the third largest fishery by tonnage caught in Darien (Landers 2011). They are especially abundant in the waters of Georgia and South Carolina, often appearing near the coasts and in the mouths of estuaries (Whitaker et al. 2010). Among the least venomous of jellyfish, the cannonball jellyfish rarely exceed 8 – 10 centimeters in diameter and have no tentacles (Whitaker et al. 2010). While adult jellyfish do have control over vertical movement, they are largely dependent on currents, tides, and winds for horizontal movement (Whitaker et al. 2010). Living in estuarine and saline water, they can tolerate a range of salinity from 17.7 to 36.5 ‰. The South Carolina Department of Natural Resources advises us to consider that these jellyfish fisheries have been decreasing in population in Asia, and that extend catching within this fishery "must take into account how the increased fishing would impact their overall role in the food web and their impact on leatherback sea turtles," as they are the main source of food for that species. According to those experienced with Darien's waters, jellyfish are highly abundant and still a nuisance when they are caught in trawling nets instead of shrimp (Griffin et al.).

Long a nuisance to fisherman, jellyfish are a relatively new industry being introduced to Darien just two decades ago when George Tai began catching and exporting the jellyballs (as they are colloquially known) to Asia (Graitcer 2012). The jellyballs are dried (losing 80 to 90 percent of their weight), preserved, and sold to distributors in Japan, Thailand, and China, where they are marketed as a delicacy (Graitcer 2012).

Jellyballs are seasonally fished during the late winter and spring, while the shrimp industry is out of season and, thus, serve as a key fishery to bridge seasons for some shrimpers (Graitcer 2012). These jellyballs can fetch between $0.06 and $0.08 per pound and, therefore, must be harvested in very large quantities.[16] Currently there are five boats that harvest jellyfish in Darien and sell their catch to Marco Seafood, the regions only jellyfish processor and exporter. This number is limited by Marco Seafood's capacity of only about 60,000 pounds (approximately one to two boat loads) at a time (Landers 2011). Interviews with local fisherman revealed that a few additional vessels also engage in the industry by selling their harvests to a west coast processing facility[17]. In order to capture the jellyballs, nets are pulled slowly through the middle and upper parts of the water column for a period of about twenty minutes (Landers 2011). While officially recognized as an experimental fishery by the Georgia Department of Natural Resources in 1998, in federal waters just three miles off the coast, it is not a recognized fishery and, therefore, largely free from regulation (Landers 2011).

3.3 SEA LEVEL AFFECTING MARSHES MODEL

SLAMM (Sea Level Affecting Marshes Model) "simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise" (Clough et al. 2010). The model was first designed in the 1980s with EPA funds and has since been improved over six versions and been utilized to project the impact of SLR on geographies as diverse as the Puget Sound, San Francisco Bay, Delaware Bay, and the South Carolina and Georgia coasts (Clough et al. 2010).

While the results of the model run by Craft et al. prove useful in understanding the projected change in marsh habitat over the next century, data by decade was not included in the publication nor made publicly available. A 2007 report by the Water Research Foundation, titled "Estimating Salinity Effects Due to Climate Change on the Georgia and South Carolina Coasts," found that in both the Lower Savannah River and Grand Strand region estuarine systems, "the relationships between sea level, freshwater streamflow, and salinity intrusion are complex and nonlinear". A decade-by-decade analysis, however, was carried out by the South Atlantic Migratory Bird Initiative (SAMBI) in order to provide a clearer understanding of the potential impacts of SLR on the wetland habitat. Our team used this SAMBI output data to better understand how sea level rise will impact Darien's commercial fishing industry.

METHODOLOGY

Drawing on a number of submodel inputs including inundation, erosion, overwash, saturation, salinity, and accretion, SLAMM incorporates geometric and qualitative relationships into a complex decision tree across sites divided into equally sized cells of five meters to 30 meters, depending on the input-data available (Clough 2010). Relative SLR is "computed for each site for each time each step" and outputs are classified into 23 land categories derived from the National Wetlands Inventory (NWI) and summarized in tabular and graphic form (Clough 2010). The model is also capable of incorporating dikes and other forms of anthropogenic modification that affect the ability of wetlands to migrate, documenting that information in the NWI data layer (Clough 2010). Finally, the model incorporates IPCC (Intergovernmental Panel on Climate Change) projections and fixed rates of global sea level

	Inundation: Non-adjacent to open water or Fetch <9km (non tropical systems)	**Erosion:** Adjacent to Open Water and Fetch > 9km (erosion)
Converting From	**Converts To**	**Converts To**
Dry Land	Transitional salt marsh, ocean beach, or estuarine beach, depending on context (see below)	Erosion of dry land is ignored
Swamp	Transitional salt marsh	Erosion to Tidal Flat
Cypress Swamp	Open Water	Erosion to Tidal Flat
Inland Fresh Marsh	Transitional salt marsh	Erosion to Tidal Flat
Tidal Swamp	Tidal Fresh Marsh	Erosion to Tidal Flat
Tidal Fresh Marsh	Irregularly Flooded Marsh	Erosion to Tidal Flat
Regularly Flooded Marsh	to Tidal Flat	Erosion to Tidal Flat
Mangrove	to Estuarine Water	Erosion & Inundation to Estuarine Water
Ocean Flat	to Open Ocean	Erosion to Open Ocean
Tidal Flat	Erosion, Inundation to Estuarine Water	Erosion to Estuarine Water
Estuarine Beach, Ocean Beach	open water	Erosion to open water

Table 3.27: Model Relationships
Source: Clough et al. 2010

rise, correct[ing] for long-term differential between local and global effects using local tide gauge trends (Clough 2010).

In the event of inundation and erosion, the model predicts changes from one type of land cover class to another. The calculations are based on a complex set of inputs over times, but the broad shift from one class to another is detailed in Table 3.27.[18]

THE SAMBI SLAMM MODEL

Conducted as part of the Designing Suitable Landscapes for Bird Species in the Eastern United States project, the SAMBI SLAMM model provided data output in 10 year increments to 2100 for much of the coastal area from southern Virginia to northern Florida (SAMBI). While the model was run for four sea level scenarios (A1B, A2, B1, and A1FI), for our analysis we have focused on the A1B scenario results, which describe "a future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies ... [and energy production is] balanced across all sources (fossil and non-fossil intensive)" (Clough et al. 2010). The A1B global SLR scenario predicts 694 mm of rise by 2100, about 30% lower than the one meter SLR projections used in this studio. The SAMBI model further selected the "protect development" option, which represents further construction of dikes around all developed areas.

Model Maximum - Total sea level change (mm)				
Year	A1B	A1FI	A2	B1
1990	0	0	0	0
2000	29	29	29	29
2010	63	65	64	64
2020	103	110	104	105
2030	153	164	149	151
2040	214	228	204	203
2050	284	299	269	259
2060	360	375	343	319
2070	442	453	430	381
2080	527	529	526	444
2090	611	602	631	507
2100	694	671	743	567

Table 3.28: Sea Level Changes in SLAMM Model
Source: http://www.ipcc.ch/ipccreports/tar/wg1/553.htm

USING THE SAMBI SLAMM DATA

The SAMBI SLAMM data, made available as raster GIS data sets, were clipped to only account for wetlands within 17.3 miles of the Georgia coast, based upon an estimated top speed of shrimping vessels of 15 knots (17.3 miles per hour). Though some shrimping vessels travel as far as North Carolina in the early season, it seems likely that the shrimping and crabbing industries would relocate to other states to be nearer the populations of commercially fished species if Georgia's estuaries failed to produce adequate supplies of these species. Further, while large white shrimp have been known to migrate far from their nursery habitats in the winter, the South Carolina Department of Natural Resources tagging studies have indicated that these shrimp are typically harvested during this migration and that the spawning stock over-winters in the local estuaries. Similarly, most blue crab also stay within a single estuary for the duration of their life. In an effort to best understand the economic impact of SLR on commercial fisheries, we have limited our data to only account for wetlands accessible within one hour of the Georgia coast.

SLAMM RESULTS

The SAMBI SLAMM model of the Georgia coast line suggested that significant changes are in store for salt marsh habitat over the next century. By 2100, the model predicts a 50% reduction in the amount of salt marsh, from 1322.25 to only 661.09 square kilometers.

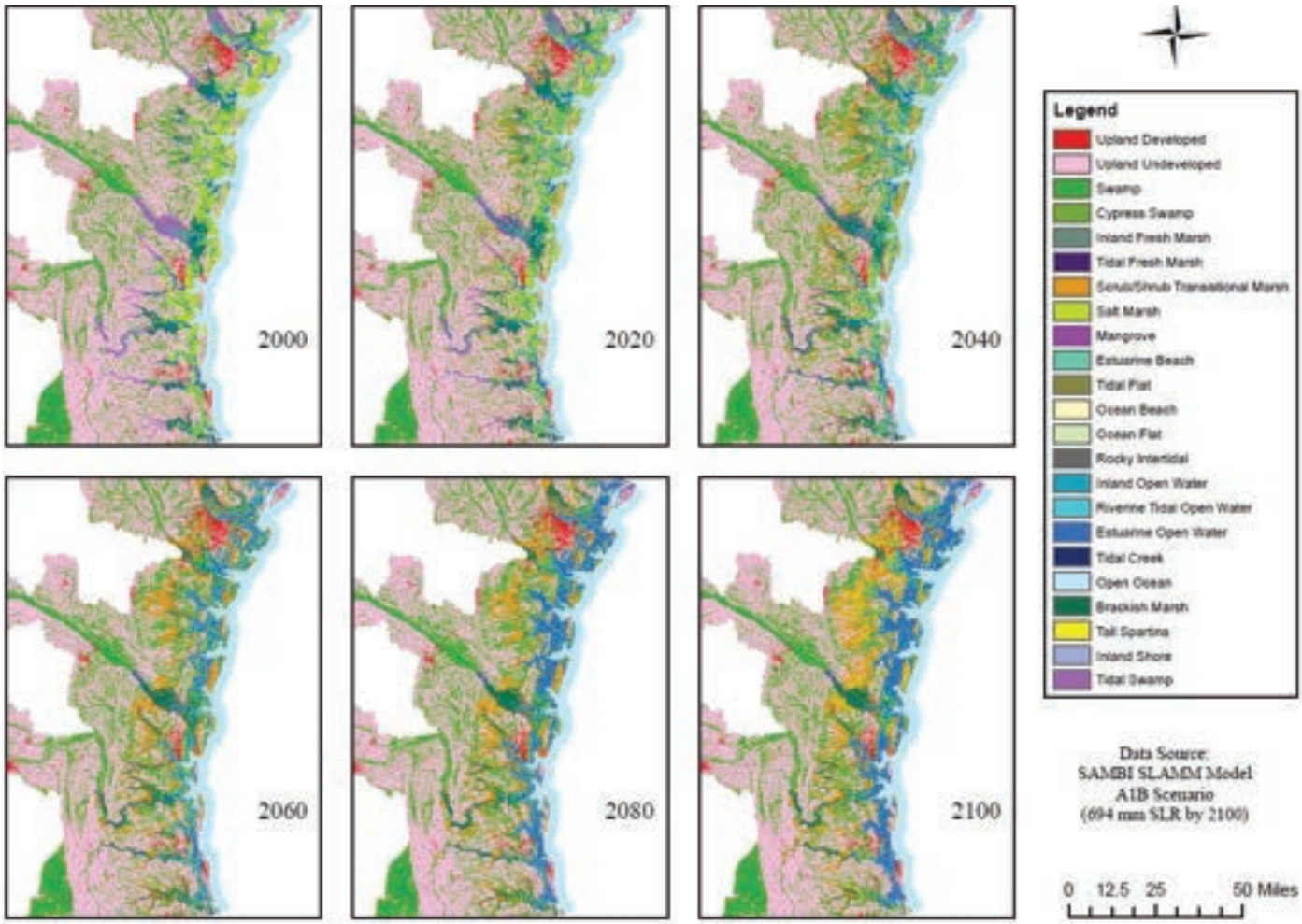

Figure 3.34: SLAMM Model of Georgia Coastal Habitat 2000 - 2010

Looking at the data by decade, however, reveals a larger trend in which salt marsh steadily decreases until reaching a low of 511 square kilometers in 2080, a loss of a full 61% of salt marsh habitat, before rebounding over the next 20 years. This rebound, in turn is driven by the abundance of new transitional marsh created over that period. The quantity of transitional marsh grew every decade except one in the model, expanding from just 25 square kilometers in 2000 to more than 1500 in 2100. These results were roughly consistent with previous studies (see Simas et al. 2001, Shenker 2009, and Craft et al. 2009). While the salt marsh (also termed regularly flooded marsh in the SLAMM technical literature) is of primary concern due to its value as shrimp and crab habitat, other land cover classifications may also play an important role in the health of these fisheries. The Wiçski et al. study suggests that "plant diversity, primary production, and nutrient recycling ecosystem functions of tidal fresh and brackish marshes exceed those of salt marshes" (Wiçski et al. 2010). Further, these habitats have historically been heavily impacted by agricultural activities and, thus, account for significantly less land area than do salt marshes (Wiçski et al. 2010). Consequently, the authors hold that fresh and tidal marshes should be considered equally important conservation targets to salt marsh. While tidal marsh do account for a significant component of the overall distribution of land cover categories, making up less than a square kilometer of land area in the model,

inland fresh marshes experience a period of marginal growth in the first half the century, followed by a steady decline which reaches an 18% aggregate decrease by 2100.

While SLAMM offers some indication of the types of changes that may occur along Georgia's coastal marshes, there are several limitations to the model that are important in gauging its usefulness. Accretion rates in the model are not affected by fresh water flow (Clough 2010). Further the model does not contain a detailed bathymetrical model, resulting in a linear salinity component and the tidal effects on estuary geometry not being predicted (Clough 2010). The overwash component contains a high degree of uncertainty with the frequency and magnitude of storms (Clough 2010). The model further lacks feedback mechanisms that can factor into accelerating SLR, for example, as indicated by Craft et al., "increasing inundation of salt marshes may increase macrophyte production and lead to increased vertical accretion" (Craft et al. 2009). Further, limitations with the input data, such as lower resolutions, may carry forward into the model (Craft et al. 2009). Finally, the model lacks a concept of "marsh health", as marsh types migrate inland basis of salinity and elevation and do not account for other ecological features (Clough 2010).

IMPLICATIONS OF RESEARCH

Commercial fishery species have been subjected to overfishing, habitat destruction, alteration of river flow regimes, and pollution, affecting the fisheries health for some time (Shenker 2009). The scientific literature indicates that rising salinity levels will have both direct and indirect impacts on the health, growth, reproduction, and survival of two of Darien's largest commercial fisheries, affecting both shrimp and crabs. Further, the studio's model clearly demonstrates significant changes in the available habitat along the Georgia Coast. With these additional stresses of sea level rise, the importance of maintaining the health of the wetlands has only grown.

A body of research exists to suggest that shifts in environmental conditions have a strong correlation with the spatial distribution of fish and aquatic invertebrates (Sumalia et al. 2011). The changes in spatial distributions could affect fishing travel times, which in turn could bring about change in the harvest levels as well as fuel and ice consumption. As much of the current fishing fleet is comprised of larger vessels, consuming larger quantities of fuel, such shifts in spatial distribution leading to uncertainty in harvest expectations and increased fishing costs may prompt a move to smaller, more fuel efficient vessels (Sumalia et al. 2011). More technologically advanced fleets may be better prepared to adapt to sea level rise by shifting to other fishing grounds, changing gear, and targeting different species (Sumalia et al. 2011).

Even without the stresses of overfishing, habitat destruction, pollution, and salinity changes associated with sea level rise, the commercial fishing industry in Darien faced a significant hurdle in competing with Asian and South American shrimp and prawn farms, which cheaply cultivate shrimp and other seafood for human consumption. The emergence of these imported shrimp in the 1990s led to a steep decline in the price per pound. Rising fuel costs, increased regulation, and unpredictable annual harvests have led dozens of commercial fisherman to exit the industry over the last several decades. The Black Gill epidemic of the past several years and the economic struggles of shrimpers associated with it may provide an early glimpse into a future of decreased financial feasibility for the industry. These impacts will undoubtedly carry through to Georgia consumers, who may find decreased availability and increased costs associated with purchasing wild caught Atlantic shrimp.

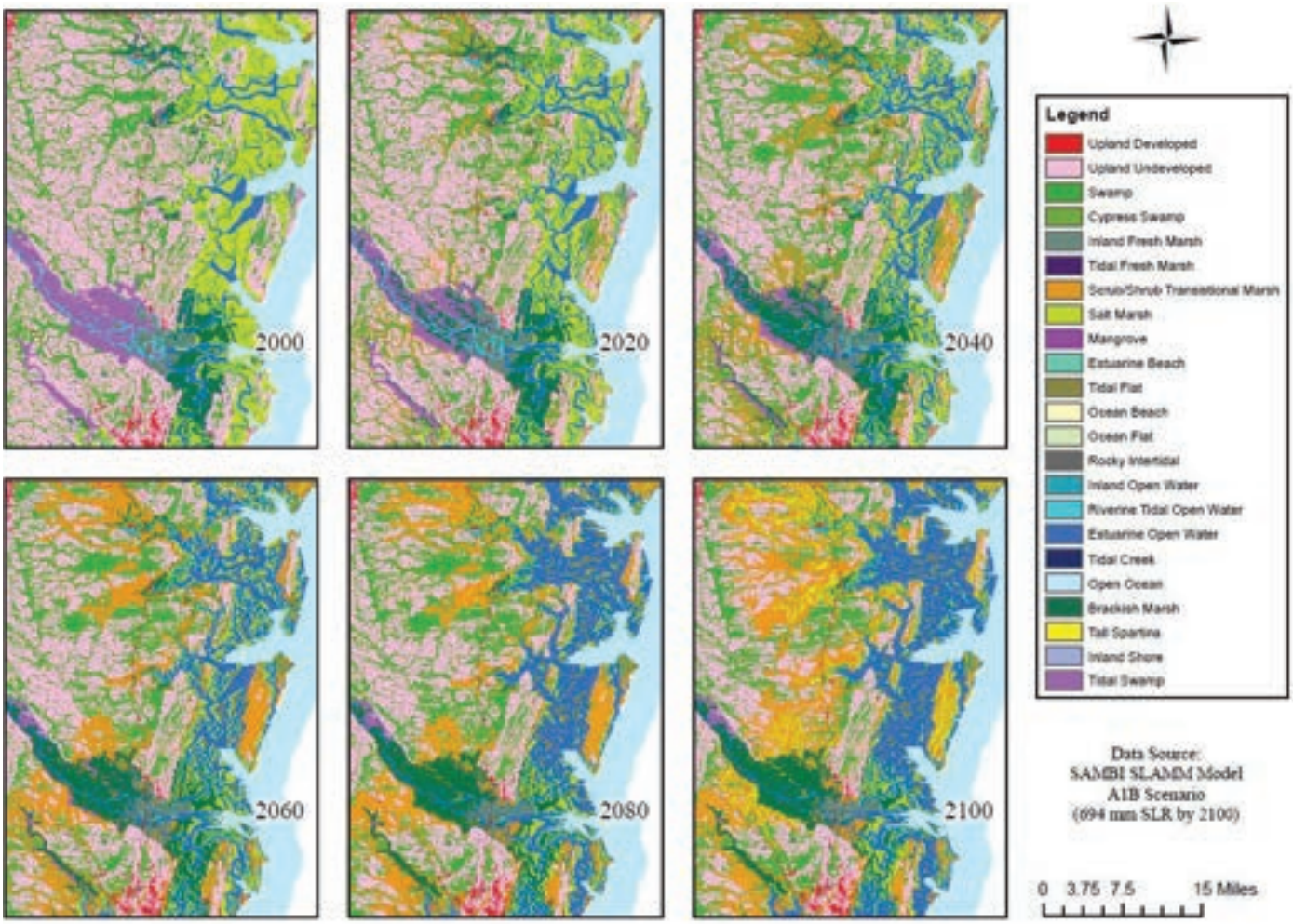

Figure 3.35: SLAMM of Glynn, McIntosh, and Liberty Counties
2000 - 2010

Due to the uncertainties and limitations noted above, we have opted to refrain from estimating direct monetary impacts from the wetland losses indicated in the SLAMM Model. A number of other studies in the past, however, have attempted to quantify the value of goods and services provided by the ecological functions of wetland habitat. A study published in Nature in 1997, for example, which estimated economic value of 17 ecosystem services (such as storm protection and flood control) across 16 biomes, including both swamps and tidal marshes, found that wetlands account for $14,785 of economic production per hectare per year (Costanza et al. 1997).[19] Of this number, habitat, food production, recreation, and cultural value accounted for a modest $304, $256, $574, and $881 respectively (Costanza et al. 1997). Much greater economic impact was attributed to disturbance regulation such as flood prevention ($4,538), storage and retention of water ($3,800), and waste treatment and pollution control ($4,177) (Costanza et al. 1997). Wiçski et al. are quick to note, however, that all wetlands "are not the same, and many do not provide the same levels of ecosystem functions" (Wiçski et al. 2010).

Historically, Darien has faced a need to shift its economy before. Once heavily focused on a timber industry, Darien shifted to reliance on oysters until overharvesting forced yet another shift to shrimping and

crabbing. Such a change may be yet another inevitable outcome of sea level rise. Some local commercial fisherman have already begun to adapt to this need, focusing on snapper, grouper, clams, and other less impacted species. The key is understood to be flexibility based upon catch limits, which in turn rely upon the health of the fishery. The limitations to this approach are the high cost of licensing and equipment, as well as specialized expertise to each commercial species.

3.4 TOURISM

Tourism is one of the world's largest industries, spanning many different sectors including restaurants, lodging, recreation, retail, real estate, car rentals, etc. (Tourism Satellite Account 2012). This makes quantifying the impacts of tourism challenging. Economic impacts from tourism can be seen through business revenues, employment, government tax revenue, distribution of income, and the use of public goods (Frechtling and Smeral 2010). The industry's broad reach touches many types of stakeholders, including private residences, public officials, business owners and managers, and employees of tourism establishments. The coastal tourism industry is very dependent on sensitive environments, and proper management of environmental tourism areas are important to yielding economic benefits.

Coastlines have long been magnets for tourists, but increasing development has caused governments to place more emphasis on sustainable development in tourism areas (Jennings 2004). The direct and indirect economic impacts of climate and environmental change will have a significant impact on many types of tourism, particularly heritage tourism and ecotourism (Tisdell 2003). This is very relevant for the state of Georgia. According to the Georgia Department of Economic Development, tourism is the second most important industry in the state, with 405,000 or 10.2% of all jobs in the state directly or indirectly sustained by tourism activities in 2012 (TSA 2012). Tourism in Georgia also generated $2.8 billion in state and local taxes and $3.6 billion in federal taxes (TSA 2012). The U.S. Bureau of Economic Analysis reported that eight million U.S. jobs were related to tourism, including 5.7 million direct tourism jobs, and 2.3 million indirect tourism jobs in the second quarter of 2013 (BEA 2013).

Rising sea levels could severely impact coastal businesses, resorts, and historic areas. Since tourism impacts so many sectors of the economy, decreases in tourism related businesses would have far reaching effects. To better understand the impacts of sea level rise on tourism, the studio team looked to both global and domestic examples.

SLR & TOURISM: WORLDWIDE EXAMPLES

Sea level rise is a global issue that is being studied in all areas of the world. Many areas are studying the anticipated impacts that rising sea levels will have on tourism. Some of the studied areas include Ghana, the Caribbean, the southern United States, and coastal Australia. One study reported that sea level measurements indicate an average SLR of 3.3 mm/year, while showing the shoreline eroded by as much as 0.86 m/year between 1974 between 2005 (Sagoe-Addy 2012). Predictions for Ghana showed 10 cm, 23.4 cm and 36.4 cm sea level rise for 2020, 2060 and 2100 respectively with 1990 as base year (Sagoe-Addy 2012). These statistics show that many of Ghana's coastal tourist facilities will be inundated by the year 2100.

In south Florida, a 60 cm sea level rise is expected to erode beaches in south Florida, with the costs of beach renourishment ranging from $1.7 to $8.8 billion. As the Port of Savannah section demonstrated, SLR may also increase the impact of major storms, a particular challenge for hurricane-prone Florida. For example,

Hurricane Georges in September 1998 resulted in revenue losses of approximately $32 million in the Florida Keys (Hall & Higham 2005). In Louisiana, the cost of protecting the city of New Orleans over the next 50 years is expected to be $14 billion as the city is expected to go from 2.4 meters below sea level to between 3.2 meters and 3.8 meters below sea level. A report by the California State Parks Division forecasts major economic impacts in California due to the impact of SLR on tourism and natural habitats (King, McGregor & Whittet 2009). Additionally, they found that economic risks and responses would vary significantly depending on what part of the coastline one looks at. For example, Torrey Pines State Beach is estimated to suffer to $5 million in damages caused by a 100-year coastal flood, and $99 million in tourism spending and local and state tax losses caused by a narrow and eroded beach.

Low-lying areas will be deeply impacted. In "The Vulnerability of Caribbean Coastal Tourism to Scenarios of Climate Change Related Sea Level Rise", an estimated 29% of resorts will be fully or partially inundated by one meter SLR; 49% to 60% of resort properties will be at risk of beach erosion (Scott, Simpson, & Ryan Sim 2012).

Unfortunately, many smaller tourist locales will be underprepared due to the lack agreement over the impacts of SLR. In North Carolina, the coastal counties generate billions of dollars a year, and have been the destination for up to 150% growth in the state's population. However, they have not taken the steps like Virginia Beach and Myrtle Beach to protect their shoreline through strategies like shoreline hardening and beach renourishment.

SLR & TOURISM: DARIEN

Tourism is often the preferred economic development strategy for many rural Georgia communities. Special interest tourism such as nature-based tourism and heritage tourism have seen significant growth in the state. The Georgia Department of Economic Development reports that Georgia is in the top 10 states in the country in heritage tourism. Darien's historic background, beautiful natural surroundings, and proximity to several sites listed on the National Register for Historic Places makes it an ideal spot for both heritage and nature based tourism. This is an important economic driver for this community.

In 2012, the Georgia Department of Economic Development reported that tourism supported 130 jobs in McIntosh County. During that same year, there was $12.9 million generated in direct tourism spending, $450,000 in state tax revenues and $370,000 in local tax revenues (GDEcD Impact of Travel on Georgia Counties 2012). From 2011 to 2012, there was a 6.7% increase in direct domestic spending, a 3.1% increase in payroll, a 2.6% increase in employment, a 5.9% increase in state taxes, and an 8.8% increase in local taxes in McIntosh County (GDEcD Impact of Travel on Georgia Counties 2012). For a county with a 10.4% unemployment rate, any disruption to the 130 jobs related to tourism would be very significant for the community.

The city of Darien uses its historic and cultural resources to attract around 25,000 tourists every year (Darien Visitor Center 2013). These resources give visitors a sense of Darien's unique identity and help tell the story of its heritage. Darien was the second settlement established by the British in the American colonies, providing a fascinating historical heritage. Fort King George is the most popular tourist destination in Darien. It was originally established as a military outpost on the delta of the Altamaha River in 1721. In the 1930s, remains of the Fort were discovered, and between 1988 and 2000, historical replicas were made to help visitors recreate the experience of the original Fort (The Times-Union). Today, the 25-acre site hosts monthly historical reenactments that

Figure 3.36: Tabby Ruins in Darien

are both entertaining and educational to visitors. In 2011, the site received 11,182 visitors. Approximately 75% of these were families, primarily visitors from the Savannah and Jacksonville regions and travelers along I-95 seeking respite from their drives (Fort King George 2012). In the future, Fort King George plans to offer more activities for tourist, such as canoe trips and camping tours. Various environmental organizations understand the cultural importance of these areas and have pledged their assistance and support in future development of the Fort.

Attracting heritage tourists is advantageous for the entire region. According to the Georgia Department of Economic Development, heritage tourists are typically more generous in their spending. On average, visitors to historic and cultural sites spend about $62.00 more per day than other types of visitors and they are more likely to spend their money on antiques, art, gourmet foods, wine, health food, and outdoor experiences such as biking, hiking, canoeing, and bird watching (GDEcD Tourism Resource Report 2011). Significant revenue comes from coastal activities and boat tours through the scenic marshlands.

There are many other sites for tourists in the region including the Butler Island Rice Plantation, the Coastal Heritage Trail, and the Colonial Coast Birding Trail, the latter two of which run along the coast of Georgia.

Darien is also the launching point for a variety of coastal tours. Altamaha Coastal Tours, a local Darien company, offers kayaking, canoeing, camping and biking. They receive about 700-800 visitors per year, and they are one of the more popular attractions in Darien.[20] They offer tours from Darien to the Blackbeard Island

Figure 3.37: Darien Docks

Wilderness area, Lewis Island, and other offshore nature preserves. Another local business owner, Captain Phillip, offers River Boat Tours, where visitors learn local history, the ecology of the area, and are able to bird-watch.

Darien's scenic waterfront and historic downtown area are popular attractions for visitors. Some of the sights in downtown Darien include the Old Jail Art Center & Museum, which displays the work of local artists. Darien River Wine and Eco Cruises give visitors a unique opportunity to see historic downtown Darien, the shrimp boat fleet, and the unspoiled marsh and river system from the water. Wines are chosen from Waterfront Wine & Gourmet, and visitors learn about the natural and social history of Darien.

Darien is also home to a fair amount of restaurant activity such as the Waterfront Wine and Gourmet, a popular wine bar in Darien's historic downtown. Other restaurants in Darien include the Purple Pickle, Skipper's Fish Camp, B & J's Steaks and Seafood, Darien River House Restaurant, and Nautica Joe's Café. Lodging in Darien includes Open Gates Bed and Breakfast, Waterfront Inn, and Fort King George Motel.

Sea level rise will have lasting implications for many of the businesses in Darien, especially those who are directly located on the waterfront or are related to ocean activities. Small businesses are often ill-equipped to deal with severe weather incidents, such as flooding. Businesses such as hotels, bars, and restaurants often have no way of continuing their business in the event of a flood. Yet, studies have shown that the majority of small business owners have been under-

insured (Clemo, 2008). The outsourcing of storage and distribution makes businesses even more vulnerable if transportation or other lines of infrastructure were damaged during severe weather or flooding (Clemo 2008). Small businesses are at great risk for being put out of business entirely in the event of a major flood or other severe weather incident. Increased incidence of flooding due to SLR and the recent changes to the National Flood Insurance Programs (NFIP) could have devastating effects on the small business community in Darien. (These will be expanded on in further sections).

Preserving attractions like Fort King George, the historic downtown, and the Coastal Heritage Trail from Sea Level Rise is critical for Darien and McIntosh County. Much of the projected SLR is expected to inundate wetlands surrounding Darien. If the presence of developed areas prevents the wetlands from migrating inland as they would with their natural process, these habitats could be jeopardized. Historic places like Fort King George, Butler Island Plantation and the tabby ruins along the waterfront in Downtown Darien, are also at risk from SLR. To better understand the impacts to specific areas and tourism related businesses, we created the following maps found below.

- Figure 3.38 displays a number of small businesses in Darien, mainly around the downtown area. The layer of blue is the projected area of direct inundation for the year 2100.
- Figure 3.39 shows the projected inundation around Fort King George.
- Figure 3.40 shows the projected inundation around the Butler Island Plantation.

These historic places are located so close to marshlands that they are severely at risk for flood damage and inundation over the next 100 years.

TOURISM, SMALL BUSINESS, & SLR: IMPLICATIONS OF RESEARCH

Darien is highly dependent on a few economic sectors, all of which are tied in some way to the ocean. Much of the tourism revolves around boat tours, kayaking, and other forms of ocean ecotourism, and the small businesses often are dependent on shrimping and seafood. Businesses owners should be educated on possible effects of SLR. Modeling indicates that the immediate impacts to the physical property in the town should be limited. Darien is located on a bluff 30 feet above sea level, meaning the land on which many of these businesses sit will not be directly affected by sea level rise. However, ecotourism could be significantly affected by alterations in the habitat, as could patterns of shrimp, crab, and other wildlife migration and spawning. The labyrinth of connections linking the well-being of the sea to the well-being of the economy should not be underestimated. For example, if a fishery fails, restaurants suffer, causing the revenue of lodging dependent on food tourism to decrease. As with any economy, there are significant interactions with the environment.

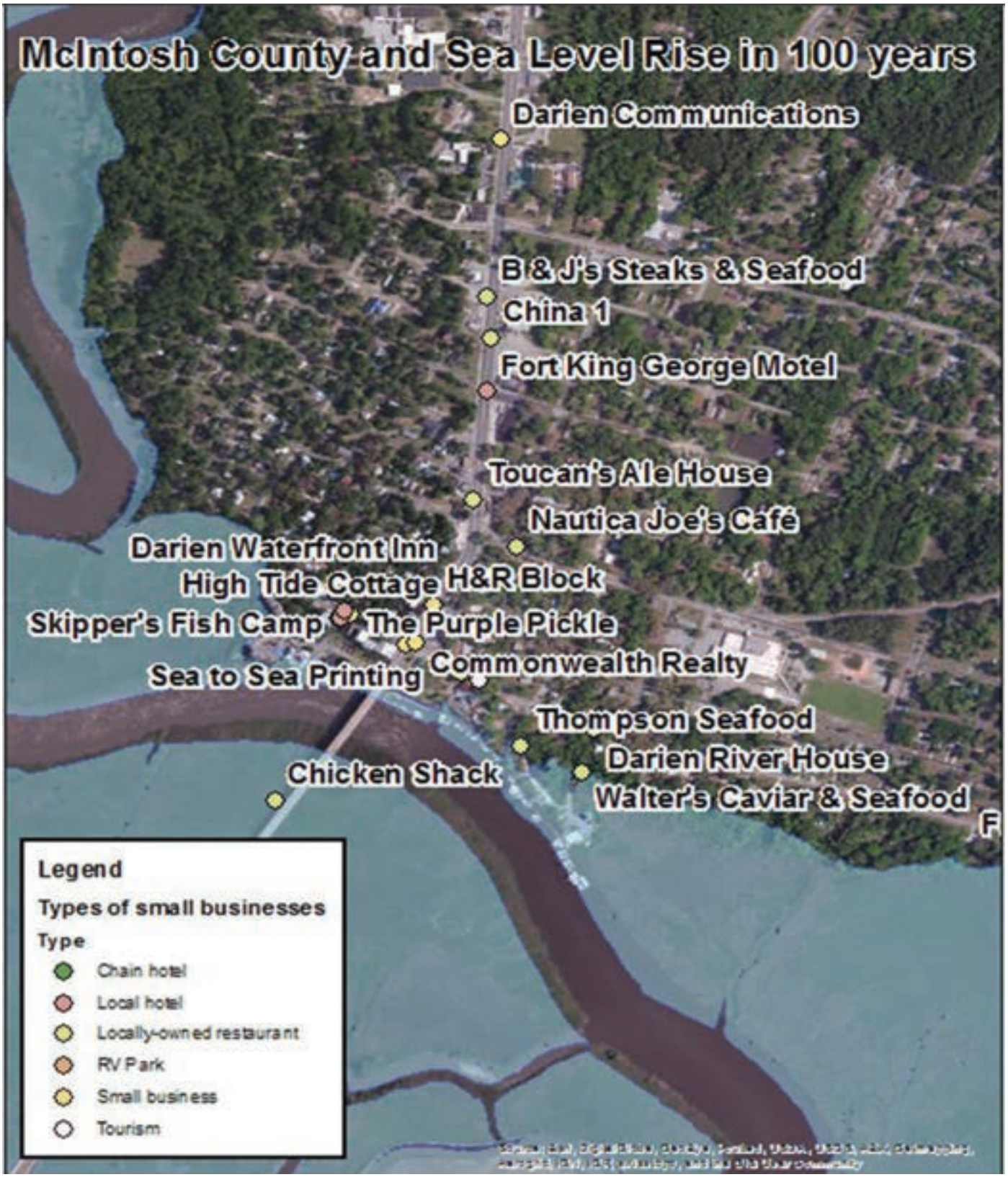

Figure 3.38: Inundation in Darien due to 1.0 Meter SLR

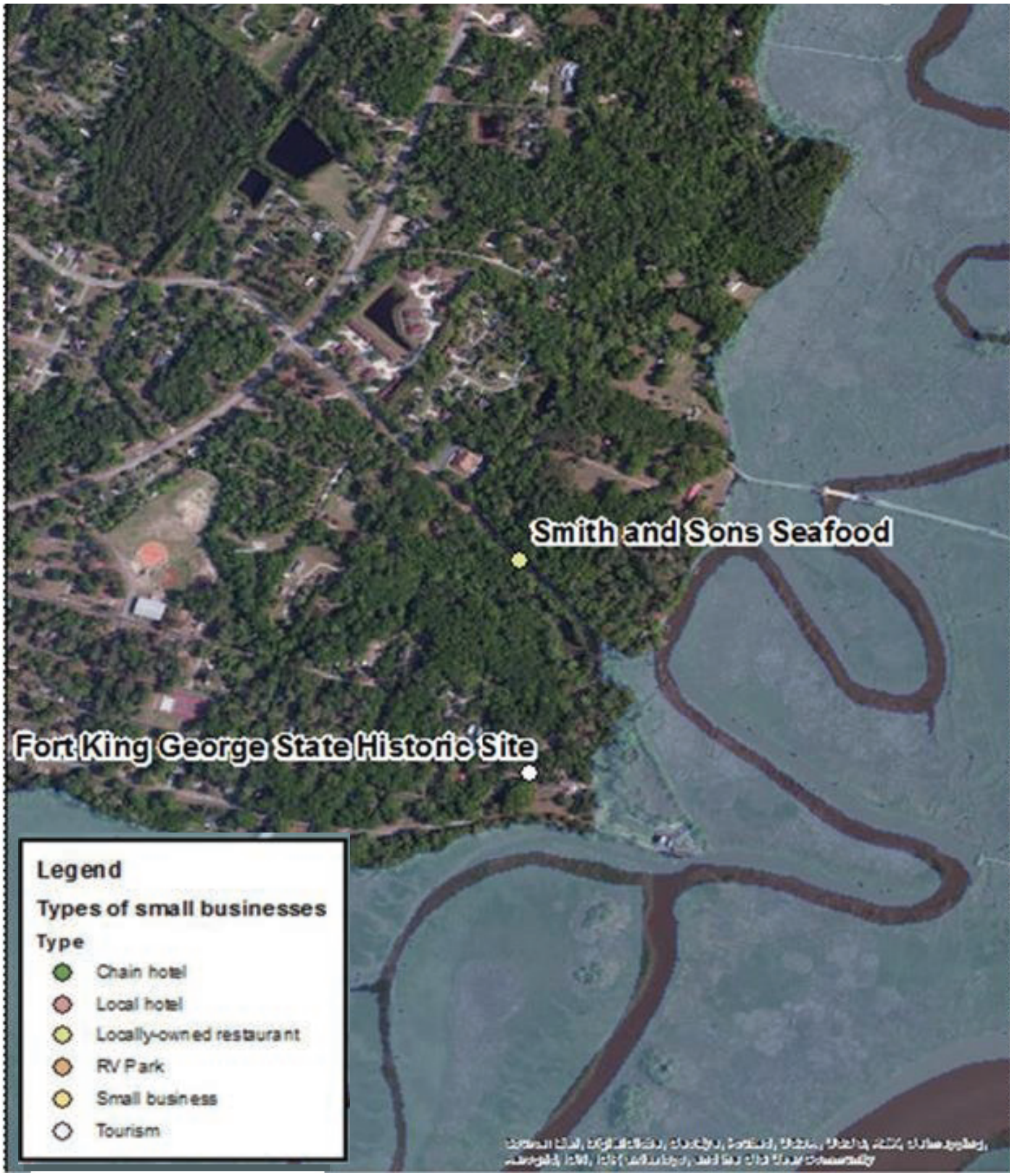

Figure 3.39: Inundation Projected around Fort King George due to 1.0 Meter SLR

Figure 3.40: Inundation Projected around Butler Island Plantation due to 1.0 Meter SLR