Coastal Wetlands and Sea-Level Rise:

A Case for Climate Adaptation Zones in Coastal Georgia

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Spring 2019

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I. INTRODUCTION

There exists within the scientific community overwhelming consensus that global sea level rise and temperature fluctuations are facilitating coastal change. Depending on local conditions, these potentially devastating byproducts of climate change introduce a diverse set of challenges, particularly to coastal wetlands and those who inhabit coastal cities. Coastal Georgia, for example, is already experiencing the increasing costs associated with maintenance and reconstruction of property and critical infrastructure that has been damaged by sea level rise (SLR) and more frequent, intense storm events; property damages alone have undergone a 300 percent increase in annual losses since 1940, reaching an approximate $1.5 billion each year from 1960 to 1980 (Horin et al. 2008, 13).

Wetlands, while highly sensitive to hydrologic and chemical imbalances caused by rising sea levels and temperature fluctuations, play an important role in the climate adaptation solution as they are a defensive ally to existing development (TNC and NOAA 2011). Such ecosystem services include: the reduction of carbon dioxide (CO_2) levels; reduced wave energy and intensity of storm surges along the coast; the filtering and processing of non-point source pollutants and sediment from runoff; and groundwater recharge and storage capacity in drought-prone areas (Association of State Wetland Managers [ASWM] 2015). Quantitative assessment of the economic value of these ecosystem services is severely understudied; however, available scientific literature indicates that wetlands do provide situational defense from storm surge (Boutwell and Westra 2015), making a strong case for coastal wetland conservation as we enter an era of climate uncertainty.

According to the United Nations Framework Convention on Climate Change (UNFCCC), over 64 percent of the world's wetlands have been lost since 1990 (UN Climate Change News 2018), and global-scale projections suggest that between 20 and 90 percent of present-day coastal wetlands could be lost by the year 2100 (Schurerch et al. 2018; UN Climate Change News 2018). Accurate assessments for current and historic wetland acreages at regional or local scales are not currently available; however, extensive draining, filling, and manipulation of wetlands due to sprawl and development pressure, confusing policies and regulations, and the spread of invasive species has become an issue of increasing concern to the public due to associated adverse impacts on wetland ecosystems. Climate change, combined with other global stressors like population growth, and increasing CO_2 emissions, will only exacerbate these effects. Coastal habitats which cannot be displaced inland or accrete sediment at a rate that equals or exceeds SLR will be destroyed or reduced in size as SLR inundates these low-lying areas (Burkett and Kusler 2000). Therefore, the scale of future wetland loss or gain depends on the degree to which coastal communities accept or prevent the landward advances of these living coastal systems into newly inundated areas (Woodruff 2018).

A. Objectives

While long-term studies of SLR impacts to coastal wetlands are available, they are limiting as they are difficult to translate to a smaller local or regional scale (Halabisky et al. 2017, 5). Thus, regional and local-scale assessments are necessary to validate the modeling tools currently used to measure global impacts of SLR on wetlands, as well as to assist relevant stakeholders and policymakers in policy development. Using available data and modeling tools, the central focus of this paper is to determine the susceptibility of coastal wetland loss to SLR in Georgia, combined with their capacity to adapt to disturbance.

Through this work, the potential vulnerability of Georgia's coastal wetlands to climate change is explored via identification of locations where inland wetland migration might be interrupted, which will facilitate identification of potential wetland migration corridors. From this analysis, the following questions are posed:

1. What existing areas can potentially serve as future wetland sites, and how much area is available for inland migration?
2. How connected are current and future migration corridors to both existing tidal wetlands and to existing conservation areas and/or public lands?
3. How can the designation of climate adaptation zones facilitate wetland migration?

B. Study Area

The area of interest (AOI) is situated below the Fall Line within the Coastal Plain of Georgia, and bounded by six coastal counties: Bryan, Camden, Chatham, Glynn, Liberty, and McIntosh (Figure 1). Additionally, it is bordered by several of Georgia's unique barrier islands, including Tybee Island, Wassaw Island, and Skidaway Island, all of which protect the mainland from severe storms.

Georgia's coast receives approximately 53 inches of rain per year, with most precipitation occurring in summer and early fall (NPS 2005). Hurricane season occurs in the summer months, and while most tropical storms generally do not reach the State, most record rainfall is connected to tropical storm systems (NOAA n.d.).

Figure 1: Study Area

In terms of percent land area, all counties are relatively competitive with each other; however, Chatham County is the largest in terms of percent land area and population. Of the undeveloped habitats and land uses in the study area, "natural" habitat is the dominant, followed closely by "open space." The natural designation consists of all forested areas, and open space consists of parks.

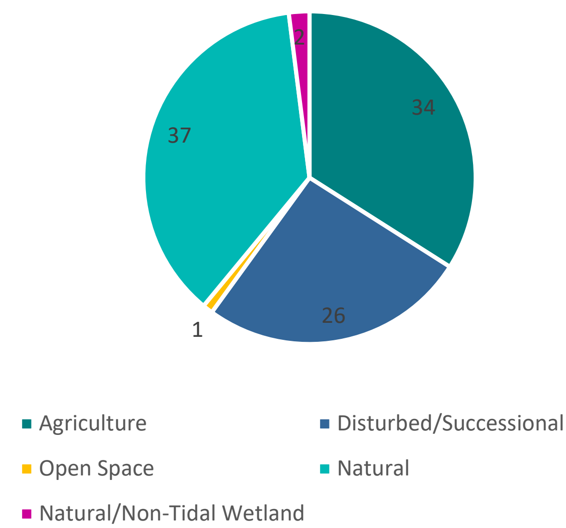

Figure 2: Percent Undeveloped Land Area in AOI

The "disturbed/successional" category referenced in Figure 3 includes successional forests that have been overrun by invasive species or otherwise impacted by anthropogenic causes. Of the 25 acres of land designated as either public or conservation, Liberty County and Bryan County host the greatest amount of undeveloped protected land, while Glynn and Camden have the least.

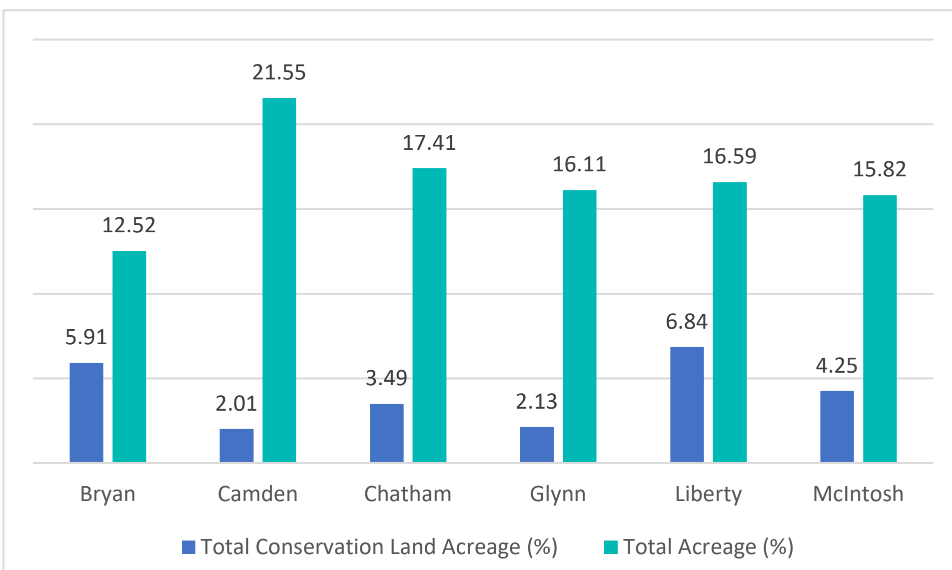

Figure 3: Percent Designated Conservation Land Area in AOI by County

C. Coastal Georgia Wetland Conditions

The low-lying coastal sections are dominated by marshes and contain slow-moving streams bordered by dense, swampy woodland. Of Georgia's 7.7 million acres of wetlands, the most extensive wetland acreage exists in the Coastal Plain at the confluence of tidal freshwater swamps and estuarine marshes (ASWM n.d., 1).

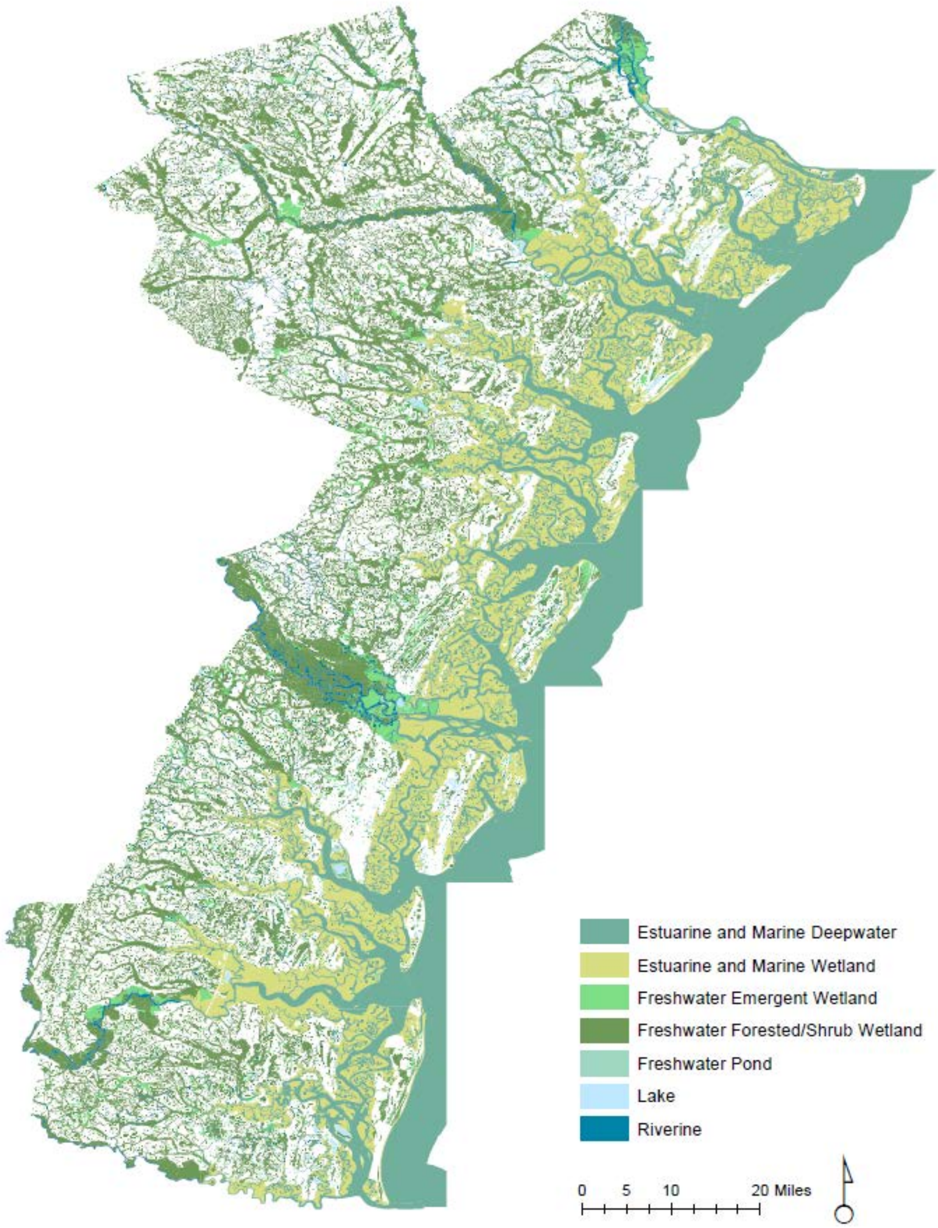

Figure 4: Wetlands within the study area

As shown in Figure 4, the six selected counties are home to approximately 378,000 acres of marshlands, or the equivalent of nearly one-third of the total salt marsh area on the east coast (Southern Environmental Law Center 2007).

The EPA's 2011 National Wetland Condition Assessment outlines the conditions of wetlands in the Coastal Plains Ecoregion. According to this report, the greatest stressors to all wetland types include vegetation removal, ditching, and surface hardening. The extent of these stressors is greatest in inland herbaceous wetlands. Similarly, high levels of nonnative plant stressors are also greater in herbaceous wetlands.

At the state level, the Georgia Department of Natural Resources (GADNR) Coastal Resources Division (CRD) releases an annual "Coastal Georgia Ecosystem Report Card." This assessment provides a quantitative account of 11 indicators related to human, fisheries, and wildlife health in coastal Georgia. The most recent Report Card revealed that the Georgia coast is in "moderately good health" as of 2017, receiving an overall score of 78 percent, or a B+ (GADNR 2017). While wetland health is not included in this assessment, it does acknowledge variables that impact wetland health, including water quality and habitat suitability.

Everhart, Justina. "Marshland Habitat, Cumberland Island, Georgia." 2010. JPEG.

In 2002, a condition known as "marsh dieback" was reported for the first time in Georgia. This phenomenon is caused by the death of marsh vegetation, resulting in bare soils that are subject to increased erosion. As of 2007, approximately 1,000 acres of Georgia's marshes have experienced marsh dieback. The exact causes are unknown but are thought to be linked to drought and salinity changes, both of which are consequences of a changing climate (Southern Environmental Law Center 2007).

II. LITERATURE REVIEW

This section is comprised of a review of related literature that first briefly highlights wetland functions and their responses to SLR, followed by an overview of wetland migration modeling and land suitability analysis techniques. Finally, it introduces existing federal and state-level policies and adaptation strategies that are used to combat wetland loss.

A. Wetland Functions

At the federal level, the term wetland means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" ([40 CFR 230.3(t)]. The value their ecosystem services bring are widely accepted among scientists; however, the services and functions provided by each wetland varies based on its type, size, and location. The United States Fish and Wildlife Service (USFWS), in collaboration with the Georgia Department of Natural Resources (GADNR), has established guidelines that can be used to better predict wetland functions at the landscape level (Tiner 2011, 3) via the publicly accessible National Wetlands Inventory Plus (NWIPlus) Database. This watershed-based preliminary assessment of wetland functions (W-PAWF) model found in the NWIPlus database can evaluate up to eleven wetland functions, which are outlined below:

Wetland Functions at the Watershed-Level

- Surface water detention
- Nutrient transformation
- Carbon sequestration
- Coastal storm surge detention
- Provision of waterfowl and waterbird habitat
- Conservation of biodiversity
- Streamflow maintenance
- Sediment and particulate retention
- Shoreline stabilization
- Provision of fish and shellfish habitat
- Provision of habitat for other wildlife

**The above functions were taken from the NWIPlus database and do not incorporate data from other relevant sources, such as state natural heritage programs* (USFWS 2010).

While some components of W-PAWF are limiting, it provides useful information regarding the weighted importance of each variable, especially for this study.

B. Wetland Responses to SLR

Historically, coastal ecosystems have adapted to fluctuating sea levels by horizontal and vertical movement across the landscape (Osland, n.d.). It is predicted that as sea levels rise in the future, coastal wetlands will migrate inland toward undeveloped, low-lying areas where migration corridors exist; however, whether wetland plant species will be able to colonize areas with different climate characteristics is highly dependent on land use patterns. Several analyses depict wetland responses to both storm surge and SLR as highly site-specific and dependent on topography, location, and ecological features of the areas (Bigalbal et al. 2018, 16) as well as more complex species-specific traits such as dispersal capacity or population growth rate (Vos et al. 2010, 1468). Further effects of SLR on wetlands might include the change of one type of wetland to another, the eradication of native or endangered flora and fauna, and the release of carbon stores and/or methane due to drying and the increased likelihood for wildfires.

C. Wetland Migration Models

Coastal ecologists have long recognized the importance of landward migration corridors in response to SLR. Progress has been hindered by serious informational gaps, since much of the available data has been collected from different sources over varying time frames at a range of scales (Spencer et al 2016); however, the steady increase in quality and availability of relevant data has resulted in a greater number of studies that have quantified landward migration (Borchert et al. 2018). Wetland migration models are most often used to explore potential future scenarios and to identify the key influences on the subject ecosystem, and they are helpful tools to guide land use planning and emergency management professionals in their decision-making processes.

According to the National Oceanic and Atmospheric Administration (NOAA), the first step in identifying suitable wetlands is to visualize the extent of projected SLR under multiple scenarios and choose the model that most accurately matches the needs of the given community (NOAA n.d.). The data requirements of each model vary in complexity. A simple model can capture key characteristics of wetland dynamics (e.g. elevation and slope) and a value for projected SLR; however, it lacks the ability to recognize the complex interrelationships between geomorphological and ecological processes that change over time, like sediment accretion and hydrodynamic flow (Spencer et al 2016).

Of the available large-scale models, NOAA's Sea Level Affecting Marshes Model (SLAMM) has been the most widely applied. This is largely due to its low computation times and implementation demands, with common parameters being tides, salinity, sediment fluctuations, habitats and species, existing development, and future development projections (Spencer et al 2016; TNC and NOAA 2011; NOAA n.d.). Given SLAMM was originally developed in the 1980s, the quality of data on global coastal wetland stocks has significantly improved, resulting in additional broad-scale models like the Global Vulnerability Assessment (GVA) and the Dynamic Interactive Vulnerability Assessment Wetland Change Model (DIVA_WCM) (McFadden 2007). Due to the complexity of the models, the GVA and DIVA_WCM will not be discussed further in this paper.

The Georgia Wetlands Restoration Access Portal (G-WRAP), created through a partnership between GADNR Coastal Resources Division, the Georgia Tech Center for GIS, and the Skidaway Institute of Oceanography with funding provided by the US Environmental Protection Agency (EPA), combines coastal data layers and NWI+ Wetlands data to make evaluation of interrelated coastal systems accessible. Among the multitude of layers, it includes a SLAMM6 dataset for coastal Georgia.

According to the SLAMM6 results, 31,202 acres of upland areas within the six coastal Georgia counties exhibit the ability to be converted to wetlands by the end of the century (Figure 5).

Though these estimates are useful, the publicly-available metadata for this layer does not provide the model's inputs, resulting in additional assumptions. Similarly, while the upland to wetland conversion for the next 100 years is mapped, discussions surrounding the establishment of conservation corridors that would facilitate migration via robust policy change have not occurred between relevant stakeholders in Georgia.

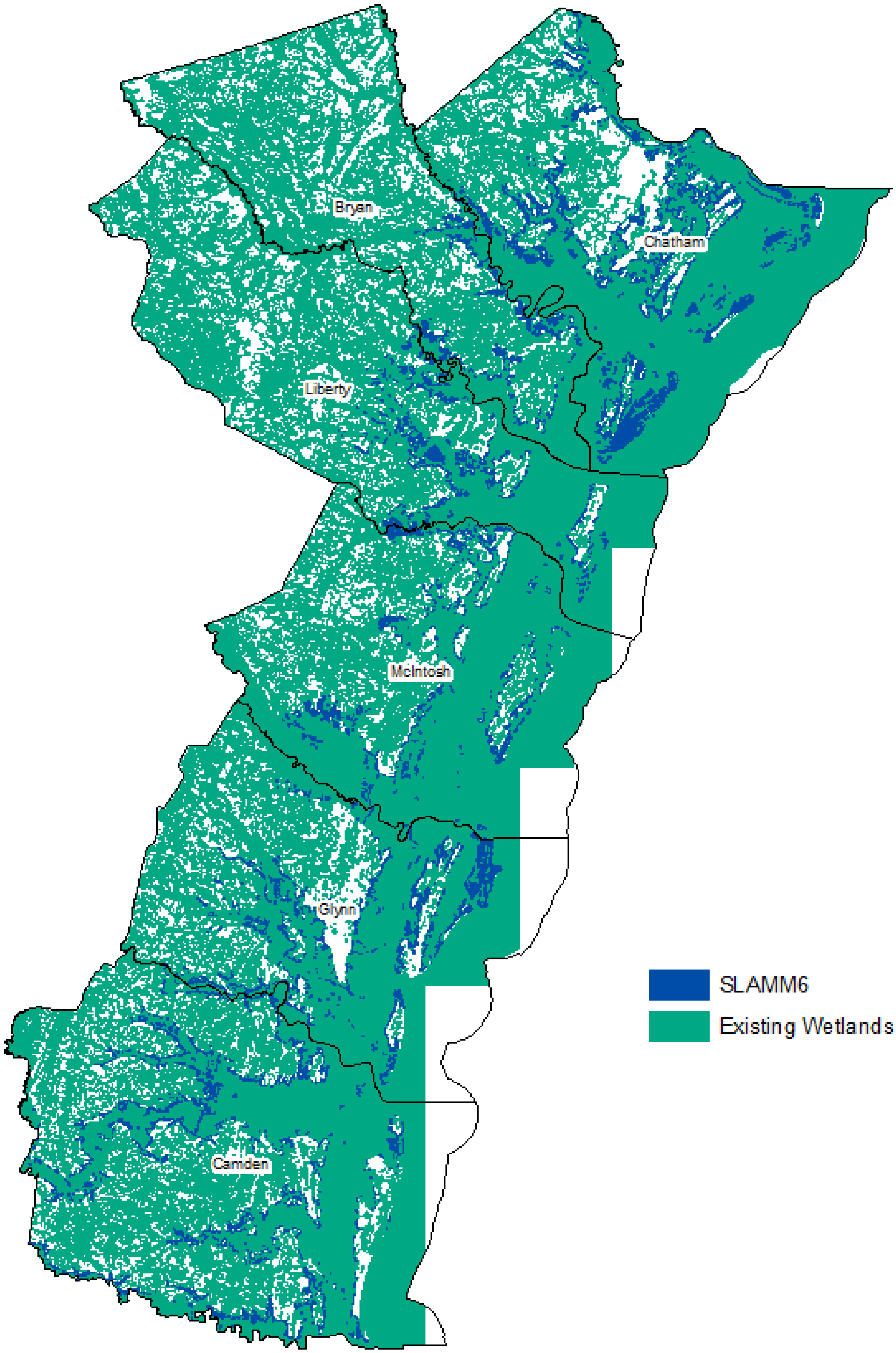

Figure 5: Wetland to upland conversion expected by 2100, compared to existing wetlands (GADNR 2016)

D. Suitability Analysis

Landscape planning, especially for wetland ecosystems, requires a multidisciplinary approach that focuses on the whole system rather than its individual parts (Opdam et al. 2008). In addition to wetland migration models, site-specific spatial datasets can be evaluated using geographic information systems (GIS) techniques to identify potential migration corridors. Recently, a study was conducted to model the most suitable locations for wetland restoration within two watersheds in Minnesota (Barrios Lopez 2015). Barrios identified four steps for prioritizing wetland restoration, which is to first specify the objectives, then identify the necessary variables and/or indicators and assign weights to each, and finally specify how the identified variables relate to each other. Variables selected for the Minnesota study include the soil saturation index, upslope drainage area, the local slope, stream order, overland flow length, water quality, and wetland proximity (Barrios Lopez 2015, 3). While Barrios' objectives were centered around wetland restoration, the same methodology can be applied to wetland migration corridors.

Several coastal states have conducted more complicated SLAMM analyses on small project areas; however, these complex models require more assumptions and more data that is often either unavailable or unreliable due to ever-changing tidal ecosystem conditions. Applying the results from more complicated but smaller-scale analyses to larger areas presents additional challenges regarding image resolution and accurate interpretation. In short, a complicated model is not necessarily more likely to yield more accurate results than a simple model, especially since the additional complexities are either likely poorly understood, or lack suitable data and modeling techniques (NROC 2015).

The Delaware Marsh Migration Suitability Analysis, conducted by the Delaware Department of Natural Resources and Environmental Control (DNREC), utilized an elevation-based GIS model that incorporated 2-foot, 4-foot, and 7-foot SLR scenarios, soil, slope, land use/land cover (LULC), and distance to tidal wetlands, and excluded impervious surfaces, developed land use, open water, and the current extent of tidal wetlands. The model did not incorporate complicated data associated with accretion, erosion, or hydrodynamic water flow (DNREC n.d.). To date, the G-WRAP database is the closest known example to the analysis conducted by the DNREC. Rather than simulate a suitability analysis, however, the G-WRAP database simply provides individual datasets (i.e. armored shore, SLAMM, shoreline change, shoreline erosion hotspots) that are intended to be used for more comprehensive analyses such as the one described in the DNREC report.

E. Existing Policies

Federal

"No net loss" is the general policy goal regarding wetland preservation in the United States. It was first mentioned by President George H.W. Bush during his 1988 presidential campaign, and Presidents Bill Clinton and George W. Bush embraced this initiative. No net loss calls for no loss of wetlands in the short-term, and a net gain of wetland quality and quantity in the long-term (Sibbing n.d.). Several federal laws explicitly protect wetlands and related species of concern using no net loss as a guiding principle, including the Clean Water Act and the Coastal Zone Management Act. The Clean Water Act was established by the EPA but permitting construction activities in jurisdictional waters of the United States occurs under the USACE.

Table 6: Existing Policies

Name	State or Federal?	Description
Section 404 of the Clean Water Act	Federal	Program predominately managed by the US Army Corps of Engineers (USACE) that regulates the discharge of dredged or fill material into waters of the US
Coastal Zone Management Act of 1972	Federal	Administered by NOAA and passed in order to encourage coastal states to develop and implement coastal zone management plans
Coastal Marshlands Protection Act (CMPA)	State	A permitting program for tidal wetlands where GADNR's Coastal Resources Division (CRD) "regulates all dredging, draining, or other alterations to marshlands;" may impose buffers to marshlands beyond the existing 50-foot buffer (ASWM n.d.).
Comprehensive Planning Act	State	Requires GADNR to develop minimum standards and procedures for the protection of wetlands and other natural resources; directs the Georgia Department of Community Affairs to incorporate these criteria into local government minimum standards and procedures; only applies to freshwater wetlands for the state, as defined under the CWA; does not include coastal marshlands (ASWM n.d.)
Revocable License (RL) Authority	State	Allows for structures to occupy water bottoms of public trust lands; issued as a component of the CMPA; can be revoked if project compliance is unmet
Georgia Shore Protection Act (GSPA)	State	Protects the sand sharing system (beaches, dunes, sand bars, and shoals)

State

Activities and construction in wetlands and public trust lands that fall under are managed by the GADNR CRD CMPA regulates activities and water-dependent structures in jurisdictional marshlands. Under the CMPA, a permit is required for marinas, community docks, bridges, dredging, bank stabilizations longer than 500 feet, modifications to any of these structures, as well as any construction not exempt from the Act. Similarly, the RL Authority of the State of Georgia is issued as a standard component of the CMPA (GADNR CRD n.d.). Focusing predominately on erosion, the SPA authorizes regulation of the development of offshore sandbars and shoals.

Management Options

Mechanisms for enabling migration are strongly related to land use, where the preferred options are to prevent development or establish easements, likely through mitigation and preservation efforts. Current management options for wetlands and SLR throughout the United States are limited to the creation of new wetlands through elevation alteration, enabling wetland migration, or some combination of the two. In addition to development, shoreline armoring is a management tactic that is severely problematic to marshland migration. It hinders the movement of species in a way that is far more permanent than the construction of residential development.

The Coastal Regional Commission has established their vision and guiding principles for natural resources in the 2017 Regional Plan of Coastal Georgia. Several performance standards relevant to wetland migration are included in the plan:

1. Implement a program for public and private acquisition and conservation easements in natural resource areas of special significance.
2. Provide incentives for shared docks for all new residential development
3. Protect undisturbed marsh hammocks
4. Undertake a restoration project that restores an environmentally significant resource
5. Adopt and implement a tree ordinance

Many of these performance standards reference the Coastal Regional Commission's 2012 Regionally Important Resource Plan, which identifies values, vulnerabilities, best practices, and policies and protective measures for wetland ecosystems. It also acknowledges state priority areas, which are areas that have been designed and nominated by State Agencies as important resource areas (CRC 2012, p. 46). The Coastal Resources Division has listed beaches, inlet sandbars and spits, marsh hammocks, shellfish growing areas, and oyster reefs as priority areas.

The outcomes of recent court cases generally rule in favor of development. For instance, in the 2008 Georgia Supreme Court Case, *Ctr. For a Sustainable Coast v. Coastal Marshlands Prot. Comm.*, 284 Ga. 736, it was determined that the CMPA does not extend to residential structures built upland from coastal marshes. Currently, there are no state or federal policies that explicitly address habitat loss from SLR (Malik 2009).

F. Climate Adaptation Zones

The Mid-Atlantic Regional Council on the Ocean's (MARCO) framework for prioritizing wetlands as natural features for climate risk reduction and resilience is spatially explicit and should be managed at a local, human scale (MARCO 2017, 7). Proposed management options provided by experts from the Association of State Wetland Managers (ASWM) include mapping of climate-sensitive wetlands; the provision of setbacks to allow coastal wetlands to migrate; water level manipulation to prevent wetlands from drying out; protection and/or restoration of connectivity; and tightened regulations of wetlands with large carbon stores (Kusler n.d.). The bulk of available literature indicates that connectivity among wetland resources is essential if coastal managers and land use planners are to ensure space for inland migration due to SLR; however, it is only recently that researchers involved in conservation planning have recognized the need for climate-wise connectivity as a recommended adaptation measure (Keeley et al. 2018, 2). Therefore, identifying ways to increase connectivity between existing coastal wetlands and future wetlands is a key focus of this paper.

One approach to implementing such measures is what Vos et al. refers to as 'climate adaptation zones' (2010, 1473). Deemed a cost-effective strategy, the purpose of a climate adaptation zone is two-fold, where wetland ecosystems would both adapt to disturbances while simultaneously facilitating migration routes for wetland species whose suitable climate zone is predicted to shift north. Suggested adaptation measures include the enlargement of existing wetlands and creation of new wetlands within the designated area; avoidance of the creation of future bottlenecks and to instead increase network density via the addition of new habitat patches; and the improvement of abiotic conditions within wetland areas (Vos et al. 2010, 1472-1473). It should be noted that climate adaptation zone policies can only be put in place once their details and benefits are fully understood; however, despite the current federal regulatory environment, this idea presents several opportunities for a variety of stakeholders to connect on small-scale solutions to the climate change.

Several relevant studies focusing on coastal wetland responses to accelerated SLR have been conducted, the majority being at a global scale. Examples of such analyses being done at smaller scales are available and occur predominately along US coastlines (Spencer 2016, Table 2). Current climate adaptation zone research and coastal wetland policies that either enable or inhibit them are limited to present conditions, thereby neglecting the migration phenomenon. Based on various gaps in available data, the results of these studies are inconclusive and suggest the need for data that covers a longer period of time.

III. METHODS

This study aims to inform Georgia's coastal land managers of the potential for future marsh and wetland migration under various sea level rise scenarios via a suitability analysis. The goal is to construct a strategic policy framework that serves to preserve the critical buffer along the coast so it is not lost to SLR. The bulk of the analysis adopted the methodology framework described in the Delaware Marsh Migration Suitability Analysis (DNREC n.d.). In addition to a suitability analysis, a habitat connectivity assessment was conducted to reinforce the necessity for additional designated conservation land that could accommodate future inland marshland migration.

The following table provides an introductory list of terms and their definitions as they pertain to this analysis. Any additional terms are defined in their respective sections.

Table 7: Key Definitions	
Estuarine area*	All tidally influenced waters, marshes, and marshlands lying within a tide-elevation range from 5.6 feet above mean tide level and below
Impervious surface**	A man-made structure or surface which prevents the infiltration of stormwater into the ground below the structure or surface (i.e. buildings, roads, driveways, parking lots, or other developed land)
Marsh*	Any marshland intertidal area, mud flat, tidal water bottom, or salt marsh
Open Water**	Areas of open water, primarily reservoirs, ponds, lakes, rivers, and estuaries
Upland*	Lands that are neither coastal marshlands nor wetlands
Wetland*	Areas that are inundated or saturated by surface or ground water often and long enough to support, and under normal circumstances, do support prevalence of vegetation typically adapted for life in saturated soil conditions (e.g. swamps, marshes, bogs, and floodplains)

**Georgia Coastal Marshlands Protection Act (Rule 391-2-3-.01)*
***GADNR Environmental Protection Division, Rules for Environmental Planning Criteria (Chapter 391-3-16)*

Shapefiles and raster imagery were obtained from the GADNR Wildlife Resources Division (WRD) Nongame Conservation Section, the US Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Geospatial Data Gateway, the Georgia GIS Clearinghouse, and the NOAA. Data required for this analysis include LULC, slope, soil, impervious surface, roads, tidal wetlands, distance to nearest tidal wetland, and Digital Elevation Model (DEM) (Table 8).

Table 8: Data Used in Analysis			
Data Layer	**File Type**	**Source**	**Year**
LULC	Shapefile	GADNR WRD Nongame Conservation Section	2009
Slope	Raster	Created from DEM	1997
Soil	Shapefile	USDA NRCS Geospatial Data Gateway	2003
Impervious Surface	Shapefile	Roads and Developed LULC	2005, 2009
Roads (all counties)	Shapefile	Georgia GIS Clearinghouse	2005
Tidal Wetlands	Shapefile	Created from LULC	2009
Distance to Nearest Tidal Wetland	Raster	Created from Tidal Wetlands	2009
DEM	Raster	Georgia GIS Clearinghouse	1996
Sea Level Rise	Shapefile	NOAA	2017
Conservation Land	Shapefile	Georgia GIS Clearinghouse	2017

Data Preparation and Assumptions

The data obtained required preparation before the analysis was conducted. All vector and raster layers were clipped to the six-county study area boundary. All vector data was converted to a 200-

meter raster. Existing raster imagery was converted to a 200-meter raster for consistency among the various inputs. Each layer was then reclassified based on a scoring system of 0 to 3, with the higher score signifying a high likelihood for marsh migration (Table 9). This scoring system was adopted from the Delaware Marsh Migration Suitability Analysis and modified to reflect the characteristics of the AOI. Additional details concerning the scoring system assigned to each input are described in the sections below.

A score of 0 indicates areas that were excluded from the analysis, such as tidal wetlands, open waters, impervious surfaces, and areas where no data is available. The higher the score, the greater likelihood the area would be suitable for inland migration. Weights were not applied to the inputs due to a lack of information regarding the significance of each parameter to wetland migration. Since the available literature does not provide a hierarchy of inputs, the input layers were weighed equally.

Table 9: Classification of Major Inputs for Final Analysis

Raster Name	0	1	2	3
LULC	No Data; water; developed		Somewhat compatible	Likely compatible
Slope	No Data	Steep (0.19° - 0.52°)	Moderate (0.06° - 0.19°)	Flat (0° - 0.06°)
Soil	No Data	Well-drained	Moderately well-drained	Poorly drained
Impervious Surface	No Data; impervious surfaces	Pervious surfaces		
Tidal Wetlands	Tidal wetlands; open water	Not classified as tidal wetlands or open water		
Distance to Nearest Tidal Wetland	No Data	Distant (10,000 – 67,727 feet)	Moderate distance (5,000 – 10,000 feet)	Proximate (0 to 5,000 feet)
Sea Level Rise	Not inundated under SLR	Inundated under SLR		

The final analysis used the newly prepared layers to create a single layer of suitability for marsh migration. The 'raster calculator' tool was used to add the LULC, slope, soil, and distance to nearest tidal wetland layers. The resulting layer was then multiplied by the tidal wetlands masking layer to exclude existing wetlands from the analysis. To exclude areas of impervious surface, this layer was then multiplied by the impervious surface layer. The final layer resulted in values from zero to twelve, with suitability increasing from zero. This layer was reclassified to a scale of one to five, with one being the least suitable and five being highly suitable.

This analysis utilized several assumptions as it was conducted using estimations based on current available data. While many factors influence the extent of tidal wetlands and future marsh migration, this analysis excluded complex parameters such as sediment accretion, erosion, salinity, and hydrodynamic flow. Areas currently classified as tidal wetlands were assumed not to migrate to tidal areas. Developed LULC categories and impervious surfaces (roads, existing structures, industrial areas, etc.) were not considered compatible with wetland migration.

Land Use/Land Cover (LULC)

The LULC layer was developed by GADNR WRD Nongame Conservation Section using aerial imagery for Georgia. Each LULC category was considered on a scale from zero to three using the methodology described in the Delaware Marsh Migration Suitability Analysis and revised as needed based on information gathered from the US Geological Service (USGS) NatureServe Explorer (2018). For instance, the original layer from GADNR did not distinguish non-tidal wetlands from "natural" areas; for this analysis, non-tidal wetlands were separated from forested areas. Similarly, areas originally defined as "natural" but were also categorized as "disturbed" or "successional" in the USGS NatureServe Explorer database were separated from the "natural" category and given a lower score. This is because disturbed and successional areas are often choked with invasive species, and while wetlands can form in these conditions, they are typically of a lower quality than those in healthy forests. A score of zero represented areas considered incompatible with marsh migration, such as developed land, rivers, and ponds. Contrary to the Delaware Marsh Migration Suitability Analysis, a score of one was not used in the LULC reclassification because the available data did not distinguish between "urban mixed development" and "developed." A score of two was applied to disturbed/successional areas and utility lines. Areas designated as natural, natural/non-tidal, open space, and agriculture were reclassified with a score of three. For this analysis, those habitats were separated into their own distinct categories. A table (see Appendix A: Land Use/Land Cover Reclassification Table) was created for LULC categories with corresponding classifications, joined to the LULC shapefile, converted from a polygon to a 200-meter raster, and masked.

Slope

A two-meter Digital Elevation Model (DEM) was obtained from the Georgia GIS Clearinghouse, which was created using LIDAR data from 1997. The slope layer was created from the DEM using the slope tool in ArcGIS. The slope range for existing tidal wetlands was extracted from the tidal wetland layer. The slope of the current extent of tidal wetlands ranged from 0° to 0.5°, while the entire area of interest ranged from 0° to 1.4°. Using Jenks with natural breaks with three categories, classification thresholds were assigned based on the current extent of wetlands. The flat category included slopes between 0 and 0.06; the moderate category between 0.06 and 0.19; and the steep category between 0.19 and 0.52. Slopes greater than those found in current tidal wetlands (0.5°) were added to the steep category because they are unlikely candidates for marsh migration. These values were then used to reclassify the original slope layer with steep lands equal to one, moderate slopes equal to two, and flat areas equal to three.

Soil

The soil layer was obtained from the USDA NRCS Geospatial Data Gateway, which was developed by the National Cooperative Soil Survey and supersedes the State Soil Geographic (STATSGO) dataset published in 2006. The soil data for the state of Georgia was clipped to the area of interest, and a new field was added for subsequent reclassification based on drainage class. The resulting layer was converted to a 200-meter raster and reclassified from seven categories to four. Well-drained soils were set equal to one, moderately well-drained soils to two, poorly drained to three, and no data to zero.

Table 10: Soil Drainage Reclassification

	Reclassified Drainage	Value
Very poorly drained	Poorly Drained	3
Poorly Drained	Poorly Drained	3
Somewhat poorly drained	Moderately Well-Drained	2
Moderately Well-Drained	Moderately Well-Drained	2
Well-drained	Well-Drained	1
Excessively Drained	Well-Drained	1
No Data	No Data	0

Impervious Surface

The impervious surface layer was created using roadway data and the LULC layer. Roadway data for the six coastal counties was obtained from the Georgia GIS Clearinghouse, merged into one contiguous layer, and converted into a 200-meter raster. The 'Select by Attribute' tool was used to select only areas that were classified as 'developed' from the LULC layer, and the resulting layer was converted to a 200-meter raster. Once the two new raster images were masked, they were reclassified on a score of zero to one, with all impervious data set to zero while all pervious surfaces as one.

Tidal Wetlands

All attributes designated as tidal, marsh, and open water were clipped from the LULC layer created by the GADNR WRD Nongame Conservation Section. A separate layer of tidal wetlands was created in order to exclude current tidal wetlands from this analysis, because existing marshes are not considered eligible areas for future marsh migration. This raster was categorized with areas considered tidal wetlands and open water equal to zero, and areas not categorized as tidal wetlands equal to one.

Distance to Nearest Tidal Wetland

Distance to nearest tidal wetlands was determined using the 'Euclidean Distance' tool, which created a new feature layer based on the tidal wetland layer (including open waters). Cutoff values for distance were determined based on the methodology described in the Delaware Marsh

Migration Suitability Analysis. The average Euclidean distance (u = 10,098 meters) from tidal wetlands was used as a cutoff for lands that were considered "distant" from tidal wetlands. The layer was reclassified with areas of No Data equal to zero, Distant equal to 1, intermediate equal to 2, and proximate equal to 3 (Table 11). This layer was then converted to a 200-meter raster.

Table 11: Distance to Nearest Tidal Wetland

	Distance from Tidal Wetlands (feet)	Value
No Data		0
Distant	10,000 – 67,727	1
Intermediate	5,000 – 10,000	2
Proximate	0 to 5,000	3

Georgia SLR Scenarios

SLR scenarios for Georgia were obtained from NOAA. Available scenarios range from zero to ten feet; however, the scenario chosen for this analysis was SLR scenarios chosen for this analysis are based on the 3-foot projection by 2100, since these years align with the available SLAMM data. After the SLR polygon was converted into a raster image, the inundated areas were reclassified to one, and all other areas were set equal to zero.

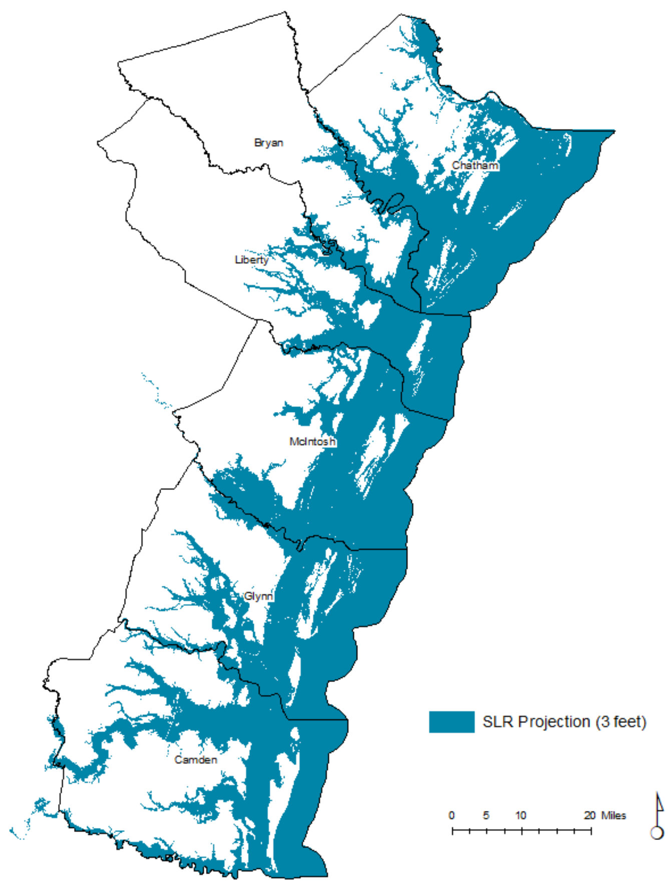

Figure 12: 3-foot SLR scenario (NOAA 2019)

Potential Priority Conservation Areas

Potential priority conservation areas were identified based on the intersection of the designated conservation or otherwise protected public land dataset with the final output of the analysis. The conservation area layer was obtained from the Georgia GIS Clearinghouse. This section of the analysis converted the final marsh migration raster to a polygon layer that contained only areas that scored as 'highly suitable' for marsh migration. The 'intersect tool' was used to isolate areas that had both high suitability for migration and intersected existing state conservation land. This was done for both existing conditions and for a 3-foot rise in sea level. The result of this action identifies potential priority conservation areas within the larger proposed climate adaptation zone network.

IV. RESULTS

The final outputs generated from this analysis are intended to be used as tools for coastal land managers to locate priority conservation areas, or climate adaptation zones, so existing wetlands can migrate inland and continue to protect residents of coastal Georgia from storm surge and SLR associated with climate change.

A. Major Inputs

Before creating the final reclassification, each of the major inputs were looked at separately to identify any potential discrepancies in the data. The following four figures are presented to visually communicate how reclassification and the selected scoring framework impacted each input.

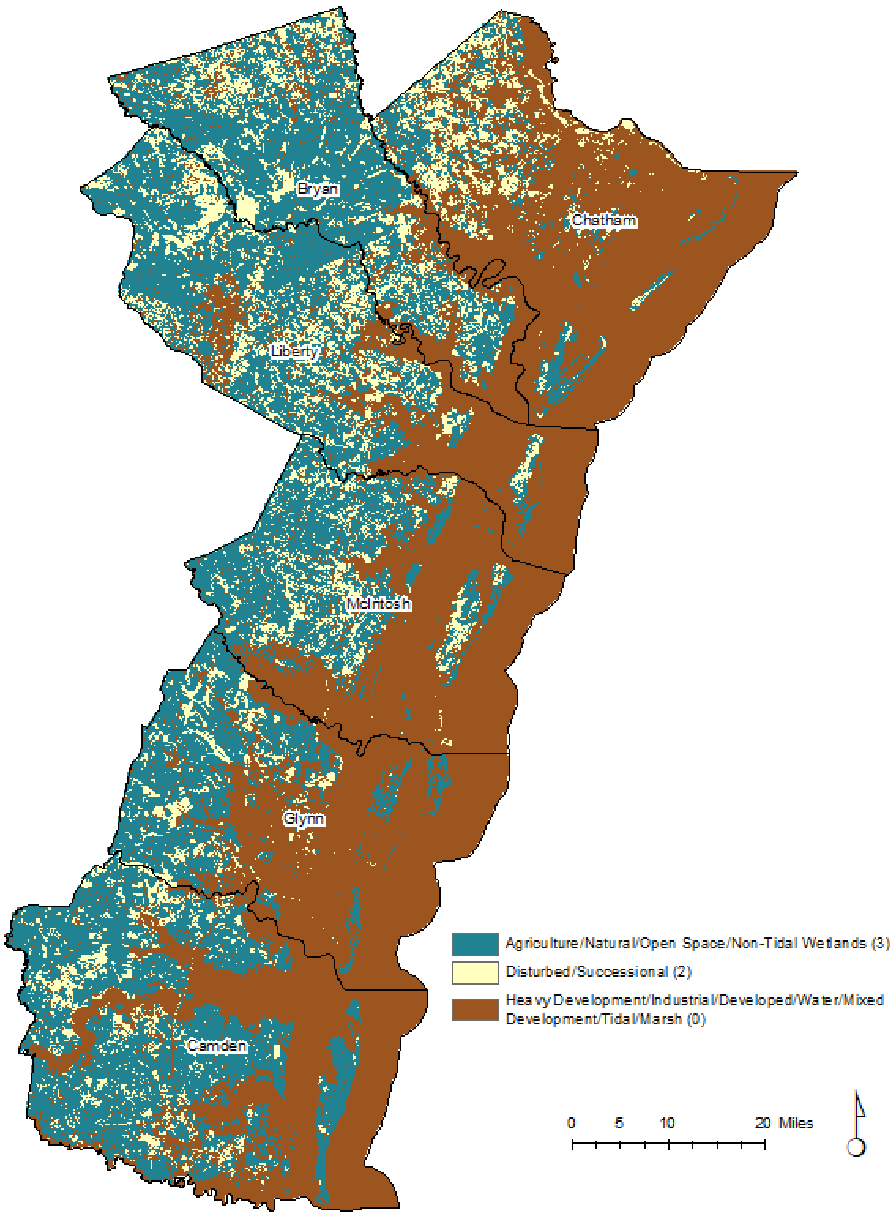

Figure 13: LULC Reclassification

The brown areas shown above in Figure 13 depict zones where marsh migration would be inhibited, either because they are existing marshlands or open water areas, or because they host existing development (i.e. where LULC received a score of zero; refer to Appendix A: Land Use/Land Cover Reclassification Table). While a score of zero for these LULCs lowered the total score of each raster cell, it did not entirely remove it from the final analysis. The yellow areas depict zones having the general characteristics that could facilitate an upland to wetland conversion but would likely need additional maintenance or special attention from land use managers to successfully convert.

In terms of slope, most areas along the Georgia coast shown in turquoise are suitable (Figure 14). This is likely due to the relatively flat geography of this portion of the state. Elevations appear to increase as you move further inland; however, some areas surrounding existing tidal wetlands were classified as having a higher slope, presumed to be reflective of the higher elevations associated with the barrier islands.

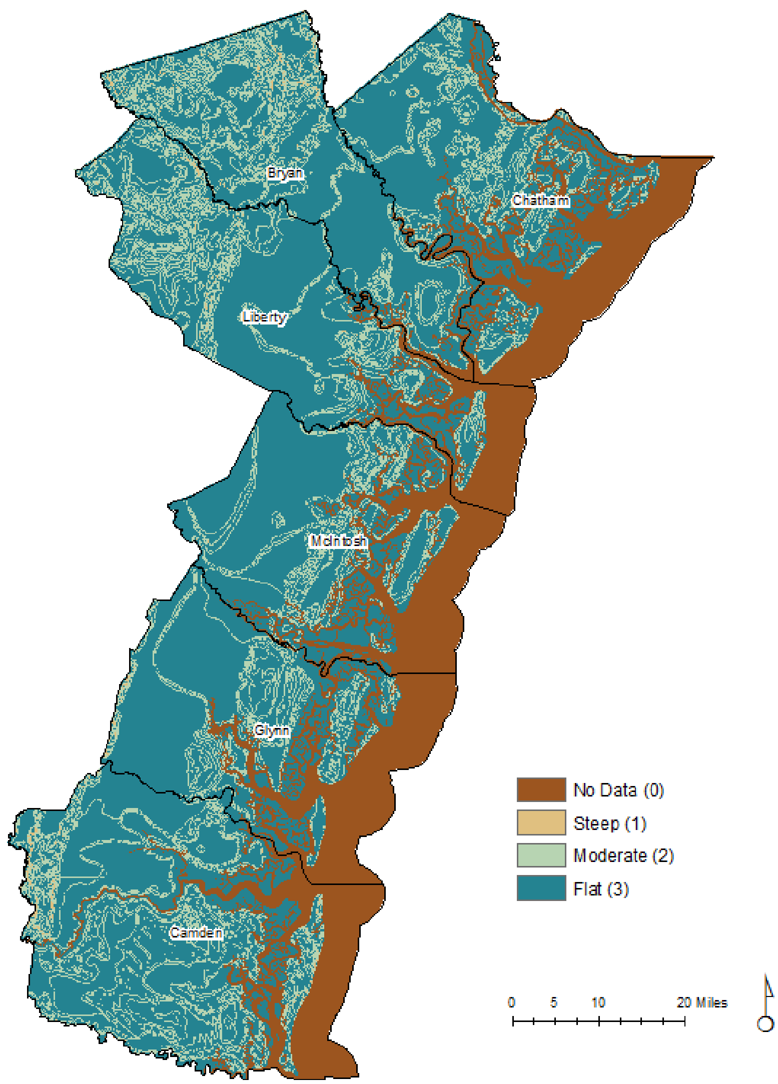

Figure 14: Slope Reclassification

Well-drained soils are more prevalent in the areas surrounding existing wetlands and tidal habitats, while moderately well-drained and poorly drained soils occur further inland. The white areas classified as "no data" scored zero as they include existing tidal wetlands and open water features, like rivers. Poorly drained soils scored the highest, moderately well-drained scored a two, and well-drained soils scored a one (Figure 15).

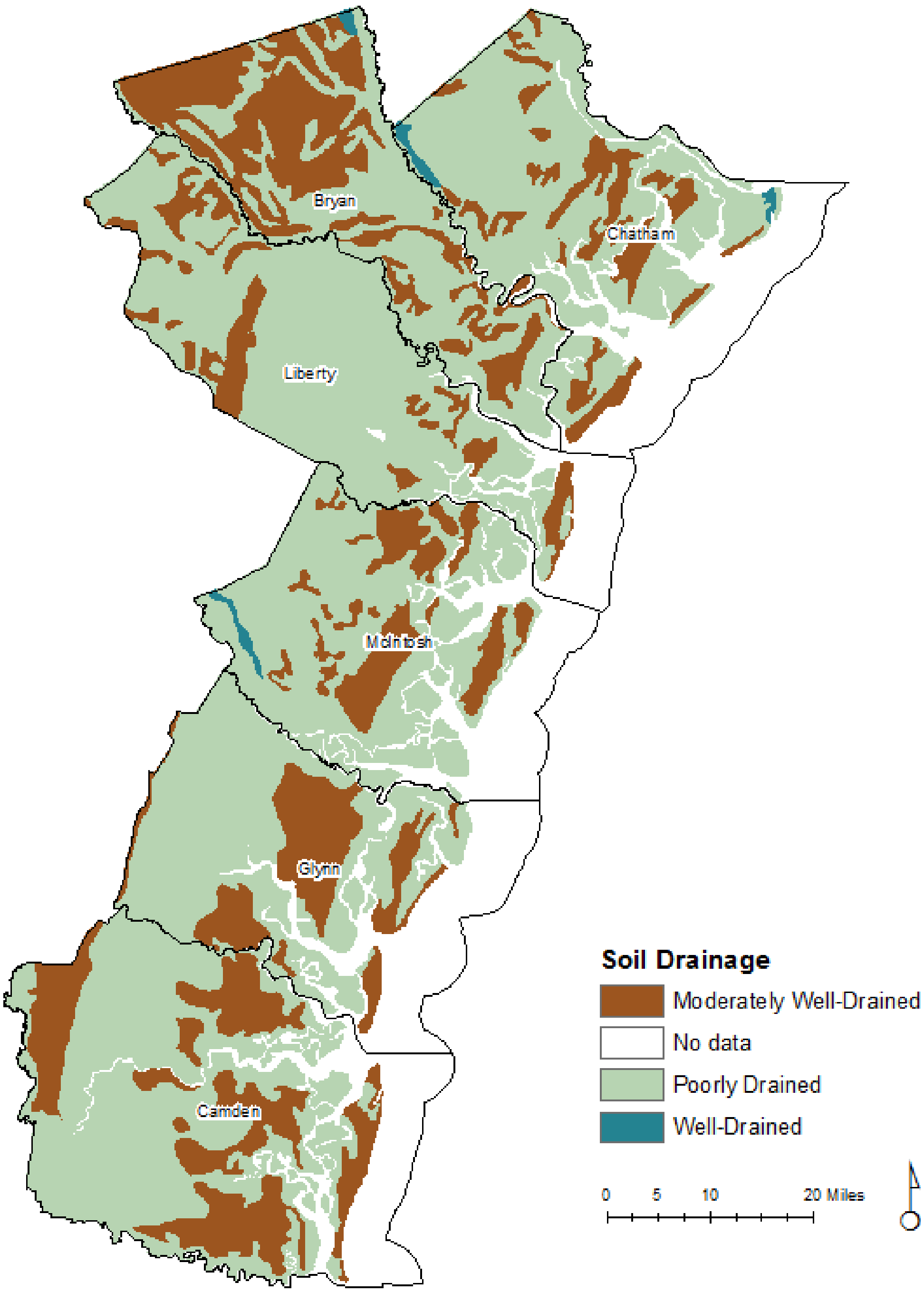

Figure 15: Soil Drainage Reclassification

As shown in Figure 16, the majority of the AOI is within 5,000 feet of a tidal wetland, which presents a higher likelihood for inland migration. This layer is potentially problematic because it assigned a higher score to areas that are considered incompatible due to other variables, such as impervious surfaces or open waters.

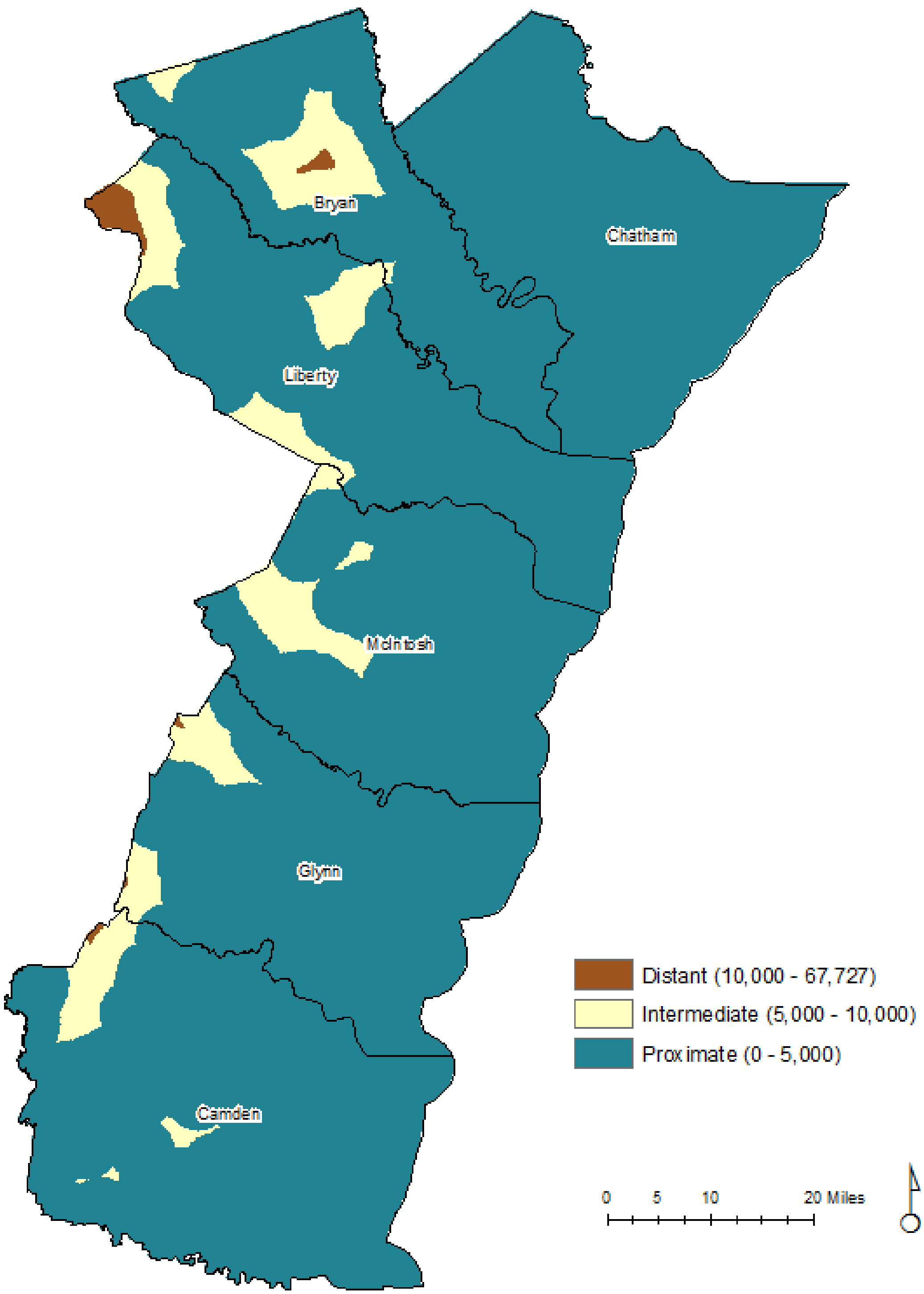

Figure 16: Distance to Tidal Wetlands Reclassification (feet)

B. Final Output and Reclassification

The final output resulted in scores ranging from zero to twelve, with zero having the least potential and twelve having the most potential for inland marsh migration (Figure 17). These scores are reflective of the sum of the scores assigned to the major inputs. Weights were not applied to the individual inputs due to a lack of information regarding the influence of each parameter to wetland migration.

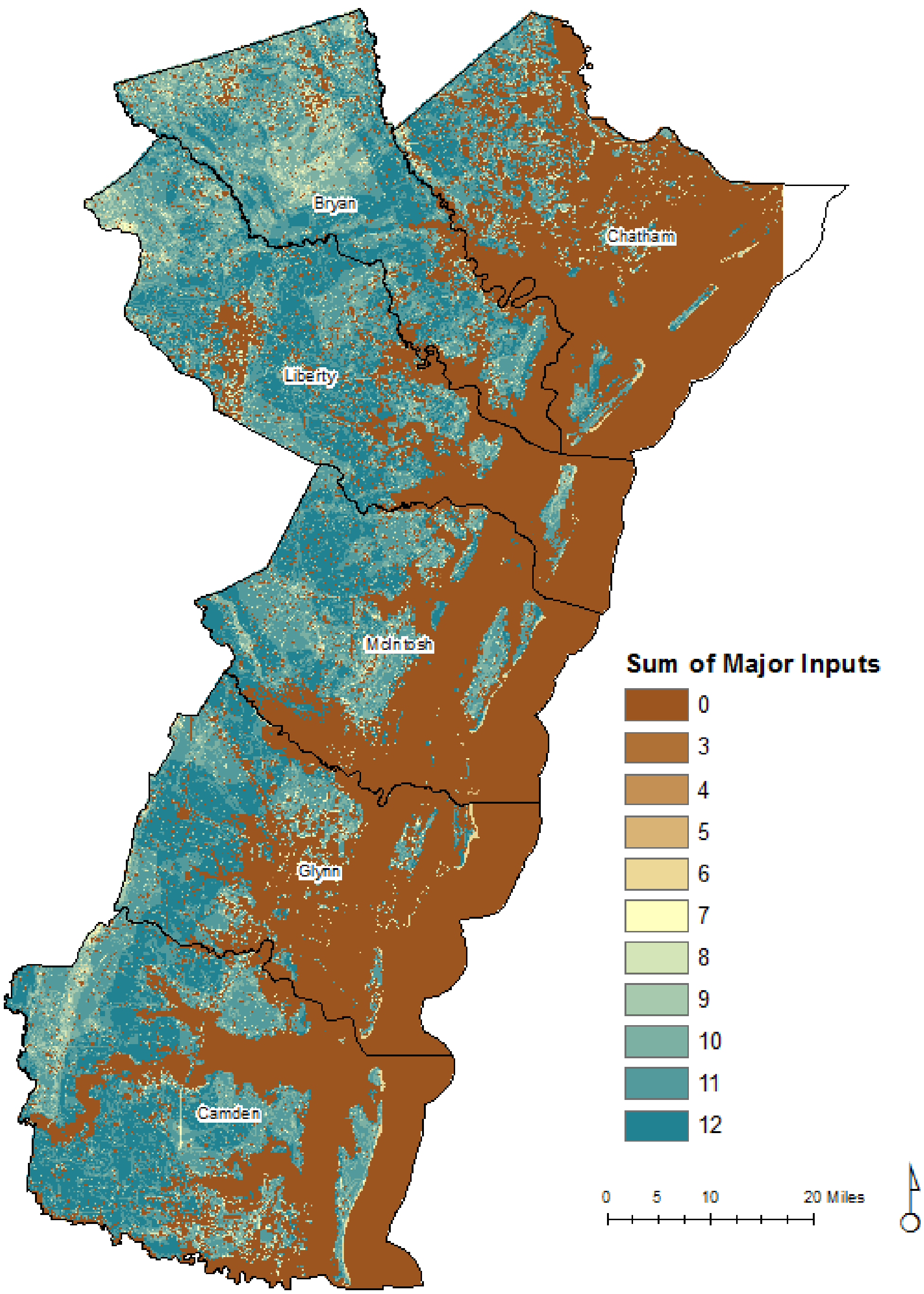

Figure 17: Final Output; Sum of Major Inputs

The final output was reclassified into five categories: Unsuitable (0), Unlikely Suitable (1-3), Moderately Suitable (4-6), Likely Suitable (7-9), and Highly Suitable (10-12) (Figure 18). A ranking of 'unsuitable' suggests that the given area is an impediment to migration, whereas areas ranked as 'highly suitable' are likely to support new wetlands in the future.

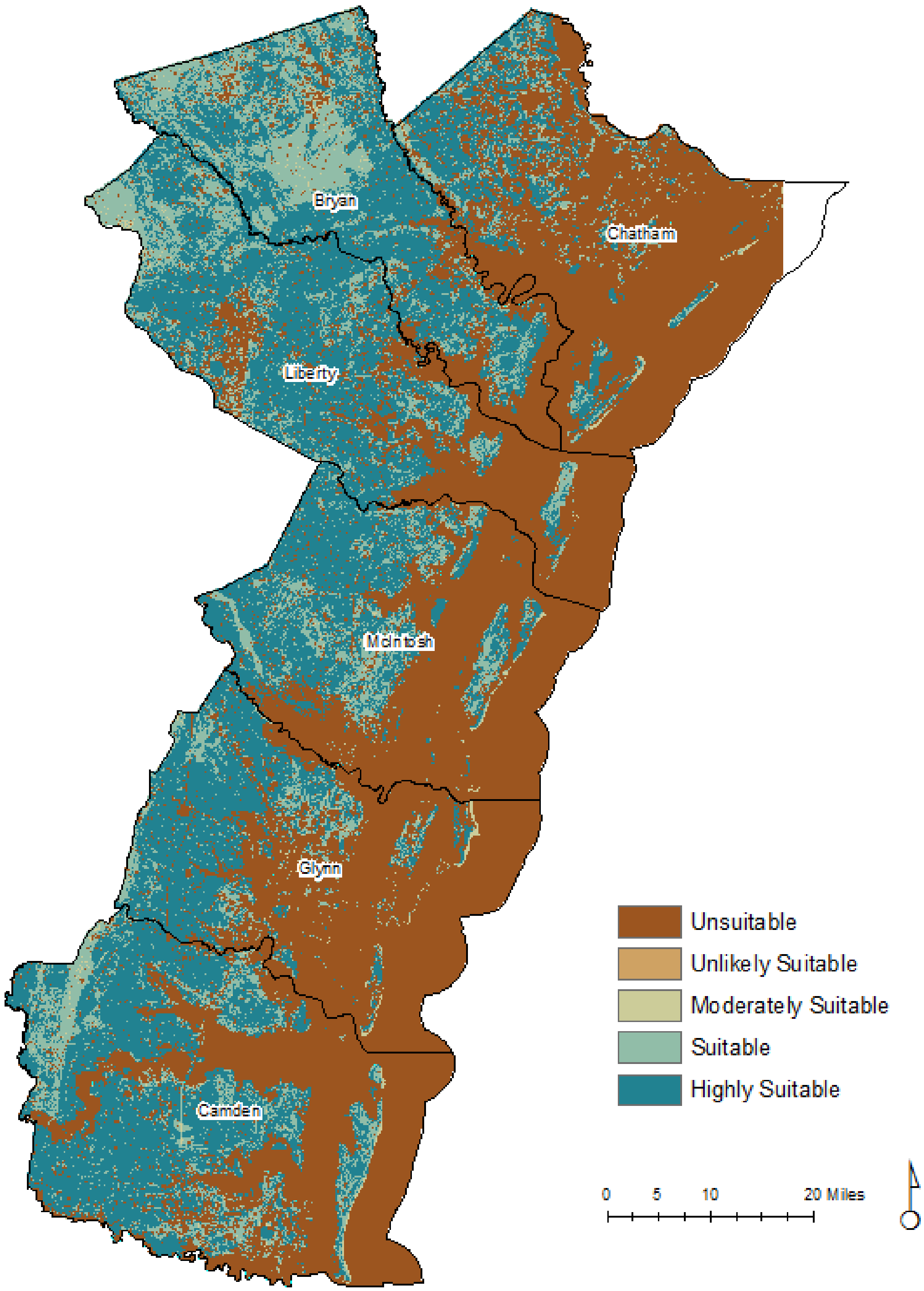

Figure 18: Final Reclassification, Migration Potential of Existing Marshlands

A simplified version of the 3-foot SLR scenario, which is the average SLR projection for this region for 2100, is shown in Figure 12. Figure 19 shows the results of the final reclassification masked to the 3-foot SLR scenario. The colored areas on the map are all at risk of being inundated under the 3-foot projection. The highly suitable (turquoise), suitable (seafoam green), and moderately suitable (lime green) areas shown within the SLR extent are the areas that are most suitable for wetland transgression.

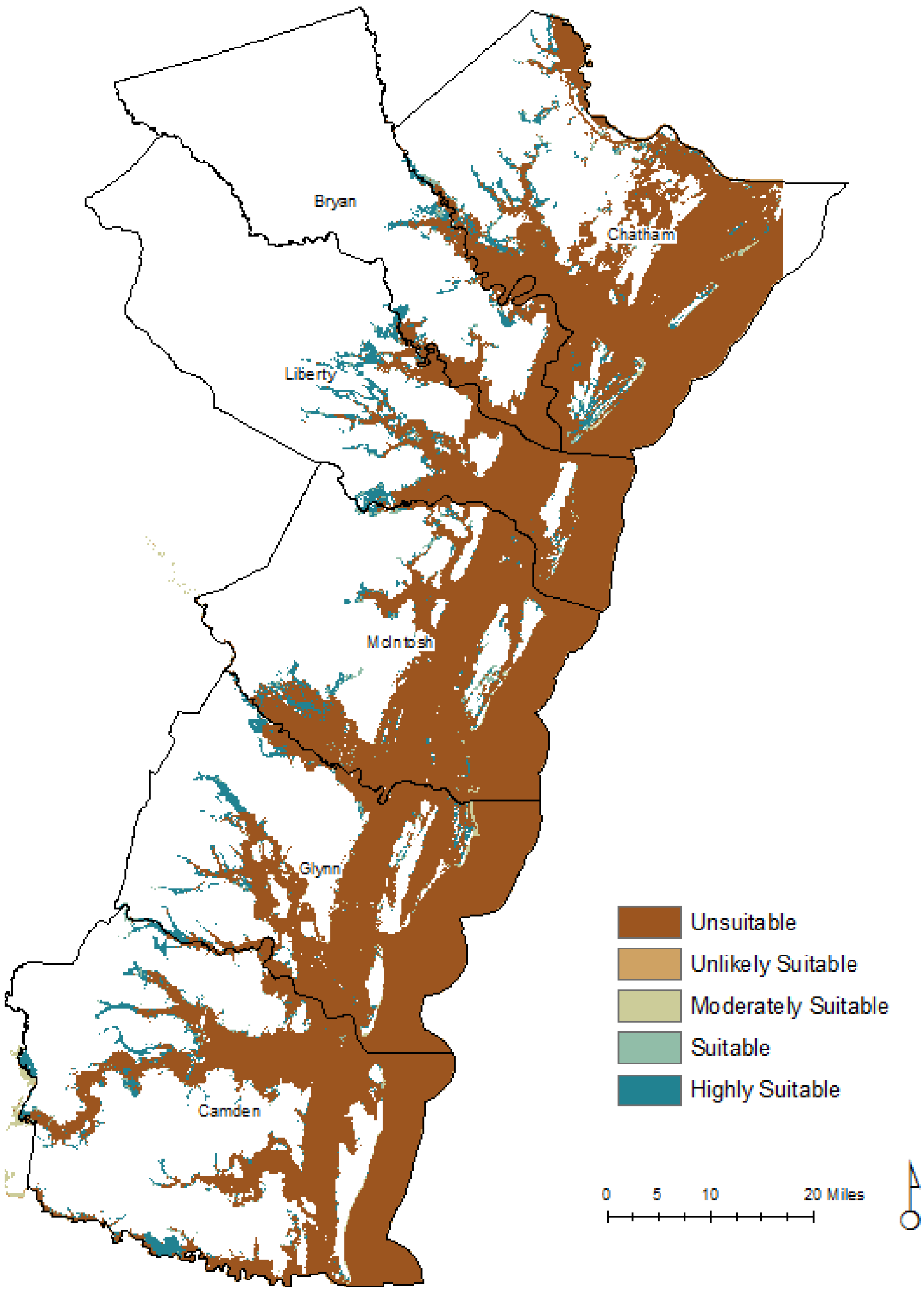

Figure 19: Final Reclassification Masked to 3-Foot SLR Scenario

C. Conservation Land and Ownership

Based on the final reclassification shown in Figure 18, approximately 59.2 percent of future tidal land (i.e. upland areas that exhibit conditions suitable to support upland to wetland conversion) is currently protected or designated as public land (dark green zones in Figure 20). The purple areas show highly suitable conservation land that is also expected to be inundated under a 3-foot rise in sea level; these areas constitute even less land area at 4.6 percent.

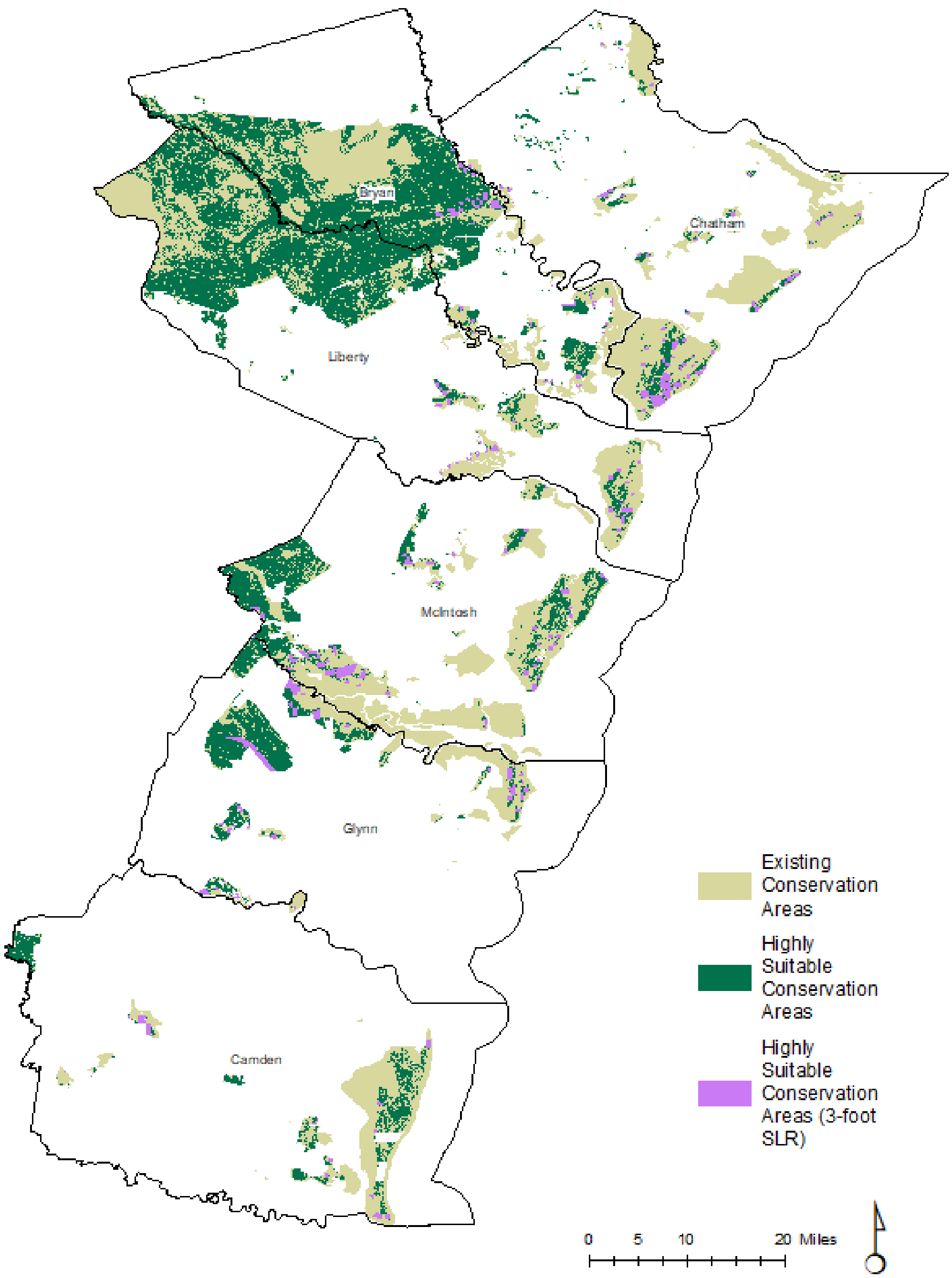

Figure 20: Highly Suitable Conservation Areas, 3-foot SLR Scenario

A total of approximately 1,418,828 acres of land would be lost under three feet of SLR. Nearly 42 percent of current marshes and tidal land within this boundary would be inundated by 2100 if the existing conditions remain the same. Of the 571,992 acres of designated conservation land in the study area, approximately 26,271 acres are considered 'highly suitable' for marsh migration under a 3-foot SLR scenario.

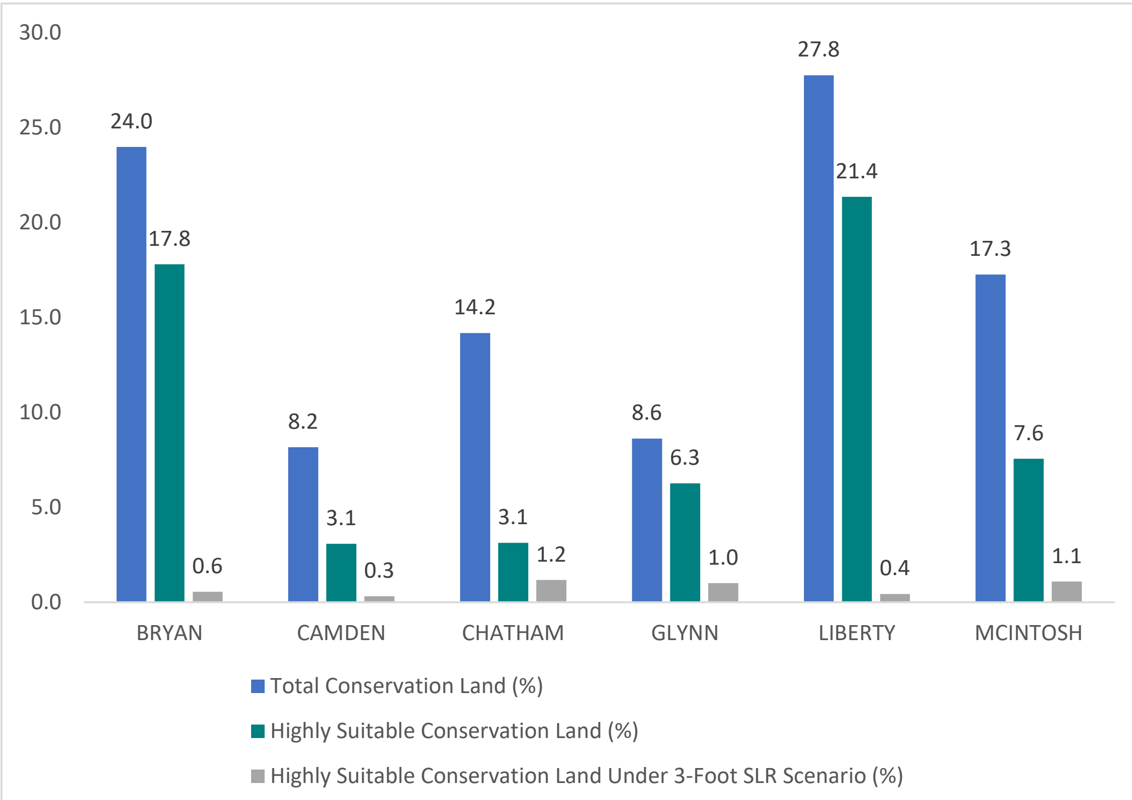

Figure 21: Percent Designated Conservation Land Considered 'Highly Suitable' for Migration

Currently, Liberty and Bryan Counties hold the highest percentage of designated conservation land. Based on the results shown in Figure 20, Liberty County holds the highest percentage of highly suitable land for wetland transgression. If the Georgia coast were to experience the projected 3 feet of SLR by the end of the century, with all other variables remaining constant, the above results shown in Figure 21 indicate that Chatham and McIntosh Counties would have the highest percentage of suitable conservation land, and Camden would have the least. Of the six counties, Chatham County would lose approximately 11 percent of its available conservation land based on the variables used in the suitability analysis; however, Chatham County also appears to retain the greatest amount of highly suitable land in a 3-foot SLR scenario. Similarly, Liberty County appears to experience the greatest percentage of highly suitable conservation land under the chosen SLR scenario (Figure 21).

Land ownership was also examined as part of this analysis since it plays a critical role in developing policy-driven solutions to effectively facilitate wetland migration as coastal areas continue to be impacted by rising sea levels. As shown in Figure 22 below, nearly half of the total highly suitable land available for migration under the 3-foot SLR scenario is owned by GADNR, while approximately 33 percent is considered private conservation land, either with or without an easement or a covenant.

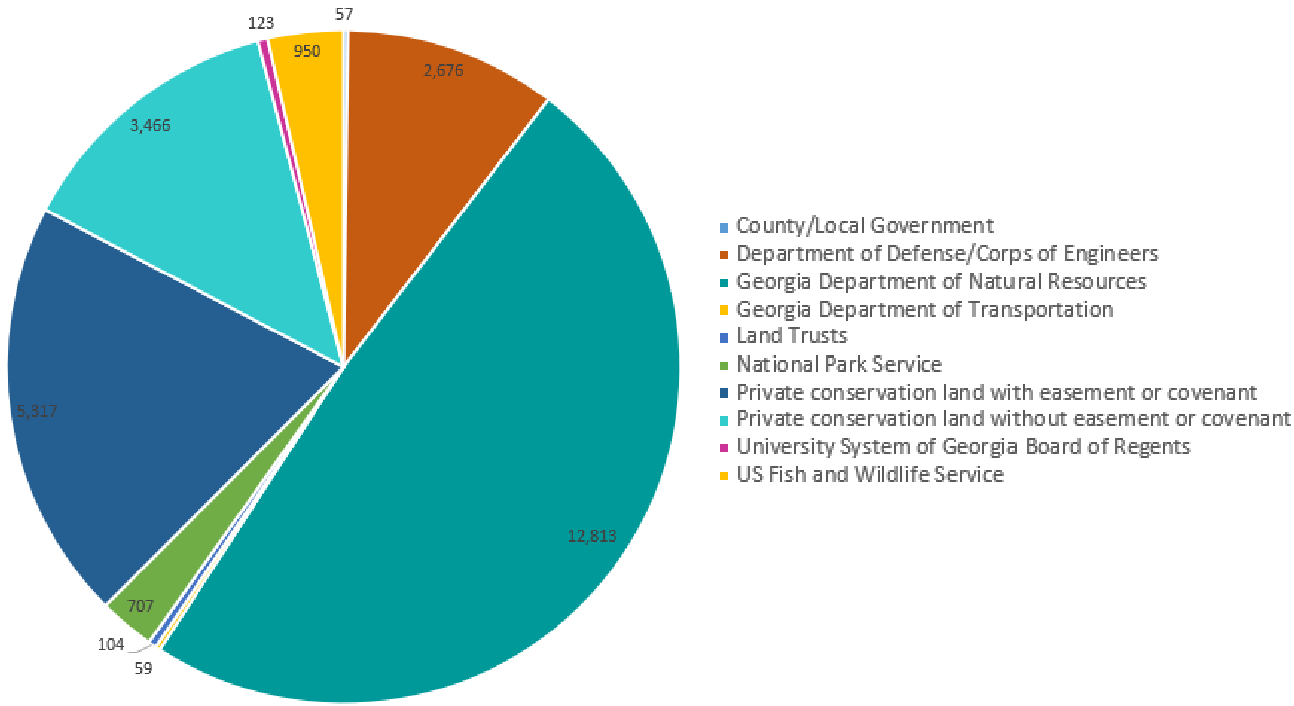

Figure 22: Land Ownership (acres)

The bulk of the remaining land is owned by federal agencies (USACE, USFWS), with marginal amounts going to other various state and local entities.

V. DISCUSSION

This analysis serves as a preliminary evaluation of wetland migration potential along the Georgia Coast. It was primarily conducted to identify existing areas that could potentially become wetlands in the future, and to quantify how much area is available for inland migration under a given amount of SLR. From those results, the connectedness between current and future migration locations and their proximity to existing conservation areas and public lands was examined to identify what management options are available and relevant to stakeholders living along the Georgia coast.

Looking at the major inputs individually, the cell size of each layer appears to have been problematic. For instance, roads, open waters, and areas otherwise with LULC that received a score of zero were considered incompatible with marsh migration (Figure 12). While this lowered the total score of each raster cell, it did not entirely remove it from the final analysis. Similarly, the distance to tidal wetlands layer was assigned a higher score in areas that are considered incompatible due to other variables, such as impervious surfaces or open waters (Figure 15). This resulted in a lower score for the individual raster cell when it should have been removed from the final analysis entirely. A potential solution that could be considered in future analyses would be the application of a weight to each score. Those areas that have been permanently impacted by development and fill material would be weighed low enough to remove any areas with these features from the analysis entirely. Additionally, further analyses should expand their scope to include higher quality imagery at lower scales, like the data used in the DNREC study (n.d.). This is because the variation between cell sizes of the original sources in this study was obvious from some of the major inputs.

Only 4.6 percent of highly suitable projected tidal land is currently either protected or designated as public in the entire study area. From this, it can be inferred that the remaining suitable areas are likely privately owned. The analysis identified several clear connective patterns that could serve as potential habitat conservation areas throughout the study area, many of which would promote connectivity between such protected lands. This potential connection is predominately shown across two counties: Chatham, Glynn, and McIntosh (Figure 20).

Given the extent of development in Chatham County, it is not surprising that it has the lowest amount of suitable land for wetland migration under existing conditions; however, at first glance, it contains the greatest percent change in acreage when comparing the results of the existing conditions to those of a 3-foot rise in sea level. Further analysis shows that those highly suitable areas identified in Chatham County are situated within Ossabaw Island Wildlife Management Area and Wassaw National Wildlife Refuge. Ossabaw Island alone currently has over 16,000 acres of tidal marshes and 9,000 acres of high ground (GADNR WRD). Similarly, Glynn and McIntosh Counties are bordered by the Altamaha River, which passes through the Altamaha Wildlife Management Area before it eventually flows into the Atlantic Ocean. Nearly the entire Altamaha River corridor is bordered by protected land (Figure 15). It can be inferred that this is likely influenced by the state-wide 25-foot buffer rule on all perennial streams, mandated and enforced by GAEPD. Similarly, the bulk of the highly suitable protected land areas that could survive a 3-foot rise in SLR are situated on existing barrier islands. Two conclusions can be drawn from this observation: a) the designation of conservation lands proves to be an effective tool in enabling marsh migration, and b) given the amount of conservation land not shown to be highly suitable indicates there is room for improvement. Because this land is already protected and owned by a state entity, land managers can begin to apply site-specific improvements to further enhance the area's potential to permit the migration of new wetland areas.

While this analysis focused on the availability for upland areas to convert to wetland areas on designated conservation land, it would be useful to introduce the element of vacancy. If vacant parcels are available in large enough quantities to justify demolition and the subsequent establishment of a conservation area, the more opportunities wetlands would have to migrate inland.

Even though some areas showed a high suitability for migration, the ability for marshes to migrate is highly complex and requires a multitude of factors that were not included in this analysis.

Similarly, those areas that were identified as having a lower score still have the potential to be converted into tidal wetlands. For this reason, the results of this analysis should be used in conjunction with the original data layers, aerial imagery, and other relevant data if they are to be used for land management purposes.

VI. POLICY RECOMMENDATIONS

The low percentage of available land for migration over the next century presents a challenge to local land managers. For one, incentivizing private landowners to not develop on their own land has historically proven to be a difficult task. The results of this analysis highlight the influence land ownership has and can continue to have on marshland migration in coastal Georgia if the right balance of policy and incentives is achieved. In addition, these results are the first step in identifying marsh migration opportunities along the Georgia coast, a goal of many other states that are working on this issue. The following recommendations, if realized, could potentially increase the amount of land suitable for marshland migration as Georgia continues to lose its coast to rising sea levels.

Redefine 'No Net Loss'

The goal of 'no net loss' as it is currently defined by the United States government establishes the need for a balance between short-term wetland losses and gains, and an increase in wetland acreage in the long term. Since its implementation in 1989 there has been no real effort to track net loss of wetland functions (Sibley n.d.). Acreage of wetland loss and gain has been tracked via the mitigation banking system, but little to no information on the quality of the new or affected resources is available. Thus, the 'no net loss' definition should be expanded from its quantitative stance to include both function and quality. 'Function' and 'quality' are inherently arbitrary and as such could include numerous factors, but some states are attempting to include more qualitative assessments in their inventories. For example, the State of Virginia has a policy that explicitly addresses a no net loss goal of natural carbon sinks for wetlands (Environmental Law Institute 2016). In Georgia, this would entail the design and implementation of a robust program, likely led by the GADNR and federally funded, that would require regular assessments of carbon storage in existing wetland areas that are deemed to be highly suitable for upland to wetland conversion. Ultimately, this would contribute to the prioritization of additional conservation areas. Alternatively, the revised 'no net loss' definition could include a spatial element, for some mitigation projects fail to meet the no net loss goal due to the urbanization of surrounding land (EPA 2008). In the case of coastal Georgia and based on the results of this analysis, preference should be given to those areas with a direct connection to the barrier islands, as well as to the counties that have the greatest amount of land suitable for wetland transgression. Opposition to this would likely come from developers and representatives from the agriculture community, and potentially the regulatory agencies as it would complicate and lengthen an already-tedious permitting process.

The issue of preservation and marsh migration would ultimately be addressed under a new no net loss definition, while the creation of new tidal marsh areas would be targeted to areas projected to be inundated by SLR. Marsh and wetland health and function must be protected by improving water quality, ensuring sediment deposition, minimizing invasive species, and preventing further habitat fragmentation.

Another product of the original 'no net loss' goal is mitigation banking. While too complex to discuss in depth in this report, it is worth noting that mitigation banking would play a role in both the revised no net loss definition as well as the establishment of climate adaptation zones, which are discussed in the below section. Mitigation banking should be expanded to focus on both current and future tidal zones. Of course, this would involve the provision of funding from both federal and state sources; however, if the regulatory framework surrounding mitigation were updated, private consulting companies would quickly adapt and alleviate the concerns of the opposition. If a municipality chooses to defend development over preventing migration, a wetland area of equivalent size and quality should be restored or preserved for future migration. Wetland preservation should be proportional based on the type and quality of the resource, with preference given to those that are scarcer. On a state level, projected transitional zones and upland to wetland areas should be added to the CRD's list of priority areas and included in local mitigation banking stocks.

Enforce Wetland Buffers

Due to perceptions of land ownership, wetland buffers or buffer zones are often controversial and therefore uncommon in many states, including Georgia. While the federal CMPA imposes a 25-foot buffer to freshwater marshes and wetlands, current Georgia state regulations currently do not impose buffer requirements to freshwater or inland wetlands (ASWM n.d.). However, some states do utilize wetland protection strategies in addition to the federal requirements. For instance, the Massachusetts Department of Environmental Protection (MassDEP) enforces the Wetlands Protection Act which protects inland and freshwater wetlands in over 100 Massachusetts communities. Each community has a designated conservation commission comprised of three to seven volunteers appointed by the city council. This entity ensures that any proposed construction or development activities will not alter protected resource areas (MassDEP 2019). Under the Act, a buffer zone is defined as the area of land within 100 feet of coastal banks, inland banks, freshwater wetlands, coastal wetlands, tidal flats, beaches, dunes, marshes, and swamps (MACC n.d.). Depending on the type and location, work proposed within 100 feet of these resources is subject to regulation from the Act and requires prior approval by the conservation commission. Another unique component of Massachusetts wetland policy is their establishment of a database that tracks protected resources. These communities have registered a total of approximately 46,000 acres of coastal wetlands and 8,000 acres of inland wetlands. The locations of these registered areas are publicly accessible and streamline the permitting process (MassDEP n.d.).

Georgia lawmakers and environmentalists have fought for the establishment of freshwater wetland buffers as recently as 2015 based on ambiguity associated with the state's Erosion and

Sedimentation Control Act. The law, which has been in effect since 1989, establishes a 25-foot buffer "along the banks of all state waters, as measured horizontally from the point where vegetation has been wrested by normal stream flow or wave action" (OCGA 12-7-1); however, because wetlands and marshes do not, by definition, exhibit wrested vegetation, the Georgia Supreme Court ruled in favor of the literal interpretation of the state law (Council for Quality Growth 2015).

The state of Georgia would benefit from the adoption of MassDEP's conservation approach. Following a standard but rigorous public involvement process, the establishment of a volunteer-based conservation commission in interested communities would be the first step. This type of organization would alleviate apprehension concerning the "wholly unnecessary, cumulative, and cumbersome new level of permitting," as expressed by the Georgia Chamber by simplifying the permit application process (Council for Quality Growth 2015). This group would then join lawmakers in advocating for updates to the outdated definitions presented in the Erosion and Sedimentation Control Act. By eliminating this damaging loophole, it would then be possible to define an explicit wetland buffer boundary that would increase habitat connectivity and ultimately better-facilitate the migration of wetlands to inland territories.

Establish Climate Adaptation Zones

If the land surrounding existing or projected tidal areas is impeded by development, migration will not occur. Similarly, land that is projected as tidal should be considered for marsh creation, even in areas where no marsh exists now. Land occurring in projected areas of SLR should therefore be designated as climate adaptation zones through regulation, easements, or land acquisition. Regulatory framework regarding wetland transgression should be enacted at the state level and implemented by local governments throughout the comprehensive planning process. The steps described above set a reasonable foundation for this to occur. Based on the results of the suitability analysis, this is particularly applicable to counties that host ecosystems suitable for migration, like Liberty and McIntosh. The funding of land acquisition and easements can be accomplished via the formation of partnerships between land conservation groups and state agencies, such as The Nature Conservancy, The Georgia Land Trust, and St. Simons Land Trust (NOAA 2011).

In addition to the identification of target wetlands, current and projected property ownership plays a crucial role in this recommendation. Given previous lawsuits involving the simple act of establishing wetland buffers, this concept is inherently controversial; however, sea levels should be allowed to rise unimpeded, particularly on vacant, underutilized, and agricultural land. Priority preservation sites should therefore be selected based on the ecological value and low acquisition cost of the existing parcel, as well as their proximity to projected transitional areas. Land trusts, while severely limited in the study area, are valuable assets that can lead other relevant stakeholders in supporting better sensible use of the landscape.

VII. CONCLUSION

The results of this analysis are intended to be used as a screening level tool for coastal land managers to determine areas suitable for future marsh migration. The variables included are only a few of many that should be included in an analysis used for plan development; further analysis should be conducted, in order to both verify these results and add to the growing repertoire of literature about wetland migration in the southeast. The final layer does not definitively depict any areas that are suitable for marsh migration; rather, it acts as one of many resources for land managers to consider during management plan development. By revisiting the existing legal framework surrounding wetlands and revising it in such a way that allows lands that fit the criteria of a "climate adaptation zone" to be legally protected from development, the potentially devastating impacts of SLR on Georgia's coast can be reduced to a manageable level. The term 'climate adaptation zone' alone is controversial; however, framing it as a culmination of steps toward the larger, progressive goal of protecting inland communities is worth considering and would ultimately contribute to a more resilient coast in the future.

Appendix A: Land Use/Land Cover Reclassification Table

GADNR Classification (2009)	GWRAP Classification (2012)	Reclass (2019)	Value
Aquaculture	Developed	Water	0
Atlantic Giant Cordgrass Marsh	Natural Vegetation	Marsh	0
Blackwater River	Rivers	Water	0
Brownwater River	Rivers	Water	0
Canal	Developed	Water	0
Common Rush Marsh	Natural Vegetation	Marsh	0
Developed	Developed	Developed	0
Disturbed Tidal Hardwood Swamp	Disturbed/Successional	Water	0
Estuarine and Inshore Marine Waters	Estuarine and Inshore Marine Waters	Water	0
Golf Course	Developed	Developed	0
Impoundment	Developed	Developed	0
Managed Former Rice Impoundment Marsh	Disturbed/Successional	Marsh	0
Oxbow Lake	Open Water/Ponds	Water	0
Parks and Recreation	Developed	Developed	0
Pond/Open water	Open Water/Ponds	Water	0
Quarry/Stripmine	Developed	Developed	0
Red-cedar - Live Oak - Cabbage Palmetto Marsh Hammock	Natural Vegetation	Marsh	0
Reed Tidal Marsh	Disturbed/Successional	Water	0
Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh	Natural Vegetation	Water	0
Southern Atlantic Coastal Plain Tidal Wooded Swamp	Natural Vegetation	Water	0
Southern Cattail Marsh	Natural Vegetation	Marsh	0
Southern Wild Rice Tidal Marsh	Natural Vegetation	Water	0
Tidal Hardwood Swamp Forest	Natural Vegetation	Water	0
Tidal Red-cedar Woodland	Natural Vegetation	Water	0
Tidal Sawgrass Marsh	Natural Vegetation	Water	0
Transitional Tidal Marsh	Natural Vegetation	Water	0
Transportation	Developed	Heavy Development/Industrial	0
Blackberry - Greenbrier Successional Shrubland Thicket	Disturbed/Successional	Disturbed/Successional	2
Disturbed Coastal Evergreen Hardwood Forest	Disturbed/Successional	Disturbed/Successional	2
Disturbed Herbaceous Wetland	Disturbed/Successional	Disturbed/Successional	2

Disturbed Sandhill Vegetation	Disturbed/Successional	Disturbed/Successional	2
Disturbed Seepage Swamp	Disturbed/Successional	Disturbed/Successional	2
Disturbed Woody Wetland	Disturbed/Successional	Disturbed/Successional	2
Early- to Mid-Successional Loblolly Pine Forest	Disturbed/Successional	Disturbed/Successional	2
Golden Bamboo Shrubland	Disturbed/Successional	Disturbed/Successional	2
Grapevine - Peppervine - Trumpetvine Thicket	Disturbed/Successional	Disturbed/Successional	2
Loblolly Pine - Sweetgum - Red Maple Saturated Forest	Disturbed/Successional	Disturbed/Successional	2
Loblolly Pine-Water Oak-Sweetgum Successional Vegetation	Disturbed/Successional	Disturbed/Successional	2
Mid- to Late-Successional Loblolly Pine - Sweetgum Forest	Disturbed/Successional	Disturbed/Successional	2
Mid- to Late-Successional Slash Pine - Loblolly Pine Managed Woodland	Disturbed/Successional	Disturbed/Successional	2
Mid- to Late-Successional Slash Pine Managed Forest	Disturbed/Successional	Disturbed/Successional	2
Open Field	Disturbed/Successional	Disturbed/Successional	2
Open Sand	Disturbed/Successional	Disturbed/Successional	2
Powerline/Pipeline	Developed	Mixed Development	2
Sand Laurel Oak / Greenbrier species Forest	Disturbed/Successional	Disturbed/Successional	2
Southern Atlantic Coastal Plain Depression Pondshore - Non Forested	Disturbed/Successional	Disturbed/Successional	2
Successional Broom-sedge Vegetation	Disturbed/Successional	Disturbed/Successional	2
Successional Slash Pine Maritime Woodland	Disturbed/Successional	Disturbed/Successional	2
Successional Sugarberry Forest	Disturbed/Successional	Disturbed/Successional	2
Successional Water Oak Forest	Disturbed/Successional	Disturbed/Successional	2
Tallow-tree Seasonally Flooded Forest	Disturbed/Successional	Disturbed/Successional	2
Tallowtree Upland Forest	Disturbed/Successional	Disturbed/Successional	2
(Water Tupelo, Swamp Tupelo, Ogeechee Tupelo) Pond Seasonally Flooded Forest Alliance	Natural Vegetation	Natural	3
(Water Tupelo, Swamp Tupelo, Ogeechee Tupelo) Pond	Natural Vegetation	Natural	3

Seasonally Flooded Forest Alliance [Burned]			
(Water Tupelo, Swamp Tupelo, Ogeechee Tupelo) Pond Seasonally Flooded Forest Alliance [Successional]	Natural Vegetation	Natural	3
Acidic Dry-Mesic Coastal Plain White Oak Forest	Natural Vegetation	Natural	3
Atlantic Coast Cabbage Palmetto Dune Swale	Natural Vegetation	Natural	3
Atlantic Coast Interdune Swale	Natural Vegetation	Natural	3
Atlantic Coastal Fringe Evergreen Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Acidic Loam Beech - Magnolia Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Bald-cypress - Water Tupelo Blackwater Small Stream Swamp Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Blackwater Levee/Bar Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Blackwater River Terrace and Ridge Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Blackwater Stream Floodplain Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Blackwater Stream Floodplain Forest [Burned]	Natural Vegetation	Natural	3
Atlantic Coastal Plain Clay-Based Carolina Bay Wetland	Natural Vegetation	Natural	3
Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin, and Baygall	Natural Vegetation	Natural/Non-tidal Wetlands	3
Atlantic Coastal Plain Swamp Island Forest	Natural Vegetation	Natural	3
Atlantic Coastal Plain Upland Longleaf Pine Woodland	Natural Vegetation	Natural	3
Atlantic Coastal Plain Xeric Sandhill Scrub	Natural Vegetation	Natural	3
Black Titi Baygall Swamp	Natural Vegetation	Natural/Non-tidal Wetlands	3

Blackwater Bottomland Hardwood - Pine Forest (High Type)	Natural Vegetation	Natural	3
Blackwater Ogeechee Tupelo Swamp	Natural Vegetation	Natural	3
Brownwater Ogeechee Tupelo Swamp	Natural Vegetation	Natural	3
Cabbage Palmetto Woodland	Natural Vegetation	Natural	3
Carolina Coastal Longleaf Pine Sandhill	Natural Vegetation	Natural	3
Carolina Willow Shrubland	Natural Vegetation	Natural	3
Cherrybark Oak - Swamp Chestnut Oak - White Oak / Switch Cane - Dwarf Palmetto / Slender Woodoats Forest	Natural Vegetation	Natural	3
Clearcut	Disturbed/Successional	Open Space	3
Coastal Plain Spruce Pine - Oak Stream Forest	Natural Vegetation	Natural	3
Coastal Salt Shrub Thicket	Natural Vegetation	Natural/Non-tidal Wetlands	3
Cypress - Tupelo Semipermanently Flooded Brownwater Swamp	Natural Vegetation	Natural/Non-tidal Wetlands	3
Diamondleaf Oak Bottomland Forest	Natural Vegetation	Natural	3
Dotted Smartweed - Smooth Beggarticks Herbaceous Vegetation	Natural Vegetation	Natural	3
Dry Acidic Eastern Coastal Plain Oak - Hickory Forest	Natural Vegetation	Natural	3
Dry Hickory Maritime Forest	Natural Vegetation	Natural	3
Dry Live Oak Hammock	Natural Vegetation	Natural	3
Evergreen High Pocosin	Natural Vegetation	Natural	3
Fire-Suppressed Longleaf Sandhill	Natural Vegetation	Natural	3
Freshwater Prairie Complex	Natural Vegetation	Natural	3
Georgia River Dune Myrtle Oak Scrub	Natural Vegetation	Natural	3
Live Oak - Cherrybark Oak - Southern Magnolia - Pignut Hickory / American Holly Forest	Natural Vegetation	Natural	3

Live Oak - Water Oak - Cherrybark Oak - Sweetgum / Dwarf Palmetto - Yaupon Forest	Natural Vegetation	Natural	3
Live Oak - Yaupon - (Wax-myrtle) Shrubland Alliance	Natural Vegetation	Natural	3
Loblolly-bay Forest	Natural Vegetation	Natural	3
Longleaf / Slash Pine Scrubby Flatwoods	Natural Vegetation	Natural	3
Longleaf Pine - Pond Pine / Chapman Oak - Myrtle Oak - Sand Live Oak - Tree Lyonia Woodland	Natural Vegetation	Natural	3
Longleaf Pine / Bluejack Oak - Post Oak / Southern Wiregrass - Sandhill Dropseed - Georgia Bear-grass Woodland	Natural Vegetation	Natural	3
Longleaf Pine / Turkey Oak - Bluejack Oak - Sand Post Oak / Michaux's Gopher-apple / Southern Wiregrass Woodland	Natural Vegetation	Natural	3
Maidencane Seasonally Flooded Temperate Herbaceous Alliance	Natural Vegetation	Natural	3
Maritime Live Oak Hammock	Natural Vegetation	Natural	3
Maritime Slash Pine - Longleaf Pine Upland Flatwoods	Natural Vegetation	Natural	3
Outer Coastal Plain Live Oak Levee Forest	Natural Vegetation	Natural	3
Outer Coastal Plain Maidencane Pond	Natural Vegetation	Natural/Non-tidal Wetlands	3
Outer Coastal Plain Shrub Titi Swamp	Natural Vegetation	Natural/Non-tidal Wetlands	3
Outer Coastal Plain Sweetbay Swamp Forest	Natural Vegetation	Natural	3
Overcup Oak - Water Hickory Bottomland Forest	Natural Vegetation	Natural	3
Pickerelweed Seasonally Flooded Herbaceous Vegetation	Natural Vegetation	Natural/Non-tidal Wetlands	3
Pond Pine - Bay Swamp	Natural Vegetation	D	3
Pond Pine - Titi Swamp	Natural Vegetation	Natural	3
Pond Pine Saturated Woodland Alliance	Natural Vegetation	Natural	3
Pond Pine Saturated Woodland Alliance [Burned]	Natural Vegetation	Natural	3

Pond-cypress Seasonally Flooded Forest Alliance	Natural Vegetation	Natural	3
Pond-cypress Seasonally Flooded Forest Alliance [Burned]	Natural Vegetation	Natural	3
Pond-cypress Seasonally Flooded Forest Alliance [Successional]	Natural Vegetation	Natural	3
Red Maple - Tupelo Maritime Swamp Forest	Natural Vegetation	Natural	3
River Birch Levee Forest	Natural Vegetation	Natural	3
Row Crop	Agriculture/Forestry	Ag	3
Saltmeadow Cordgrass - Panicgrass Species Brackish Herbaceous Vegetation	Natural Vegetation	Natural	3
Sand Cordgrass - Seashore Mallow Herbaceous Vegetation	Natural Vegetation	Natural	3
Sand Laurel Oak - Mixed Hardwood Upland Forest	Natural Vegetation	Natural	3
Sand Laurel Oak - Sand Live Oak Hammock	Natural Vegetation	Natural	3
Sand Live Oak - Myrtle Oak - Chapman Oak Shrubland Alliance	Natural Vegetation	Natural	3
Sandhills Swamp Blackgum Hillside Seepage Forest	Natural Vegetation	Natural	3
Sawgrass Head	Natural Vegetation	Natural	3
Sea-oats Dune Grassland	Natural Vegetation	Natural	3
Sea-oats Temperate Herbaceous Alliance	Natural Vegetation	Natural	3
Seaside Greenbrier / Camphor Goldenaster - Trailing Wild Bean - (Sea-oats) Herbaceous Vegetation	Natural Vegetation	Natural	3
Shining Fetterbush - Inkberry Saturated Wooded Shrubland Alliance	Natural Vegetation	Natural	3
Shining Fetterbush - Inkberry Saturated Wooded Shrubland Alliance [Burned]	Natural Vegetation	Natural	3
Slash Pine - Pond-cypress Basin Swamp	Natural Vegetation	Natural	3
Slash Pine - Pond-cypress Saturated Woodland Alliance	Natural Vegetation	Natural	3

Slash Pine - Pond-cypress Saturated Woodland Alliance [Burned]	Natural Vegetation	Natural	3
Slash Pine - Pond-cypress Saturated Woodland Alliance [Successional]	Natural Vegetation	Natural	3
Slash Pine Flatwoods	Natural Vegetation	Natural	3
South Atlantic Coastal Nonriverine Swamp Forest	Natural Vegetation	Natural	3
South Atlantic Coastal Plain Dry Longleaf Pine Sandhill	Natural Vegetation	Natural	3
South Atlantic Coastal Plain Longleaf Flatwoods	Natural Vegetation	Natural	3
South Atlantic Coastal Plain Pine Flatwoods Complex	Natural Vegetation	Natural	3
South Atlantic Coastal Plain Wet Pine Flatwoods	Natural Vegetation	Natural/Non-tidal Wetlands	3
South Atlantic Coastal Pond	Natural Vegetation	Natural/Non-tidal Wetlands	3
South Atlantic Coastal Shell Midden Woodland	Natural Vegetation	Natural	3
South Atlantic Mixed Oak-Pine Calcareous Flatwoods Forest	Natural Vegetation	Natural	3
South Atlantic Swamp Island	Natural Vegetation	Natural	3
South Atlantic Upper Ocean Beach	Natural Vegetation	Natural	3
South Atlantic Wet Slash Pine Flatwoods	Natural Vegetation	Natural	3
South Atlantic Willow Oak Flatwoods Forest	Natural Vegetation	Natural	3
Southeastern Coastal Plain Xeric Hammock	Natural Vegetation	Natural	3
Southeastern Florida Maritime Hammock	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Carolina Willow Dune Swale	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Depression Pondshore - Forested	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Depression Pondshore - Forested [Burned]	Natural Vegetation	Natural	3

Southern Atlantic Coastal Plain Depression Pondshore - Non Forested [Burned]	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Large River Floodplain Forest	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods [Burned]	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods [Successional]	Natural Vegetation	Natural	3
Southern Atlantic Coastal Plain Xeric River Dune	Natural Vegetation	Natural	3
Southern Coastal Plain Herbaceous Seep and Bog	Natural Vegetation	Natural	3
Southern Coastal Plain Hydric Hammock	Natural Vegetation	Natural	3
Southern Coastal Plain Mesic Slope Forest	Natural Vegetation	Natural	3
Southern Coastal Plain Nonriverine Basin Swamp	Natural Vegetation	Natural	3
Southern Coastal Plain Oak Dome and Hammock	Natural Vegetation	Natural	3
Southern Hairgrass - Saltmeadow Cordgrass - Dune Fingergrass Herbaceous Vegetation	Natural Vegetation	Natural	3
Southern Planted Pine Complex	Agriculture/Forestry	Ag	3
Southern Planted Pine Complex (Sandhill)	Agriculture/Forestry	Ag	3
Swamp Blackgum - Mixed Hardwood Small Stream Forest	Natural Vegetation	Natural	3
Swamp Blackgum Bayhead Forest	Natural Vegetation	Natural	3
Swamp Blackgum Floodplain Forest	Natural Vegetation	Natural	3

Swamp Titi - Large Gallberry - (Black Titi) Saturated Shrubland Alliance	Natural Vegetation	Natural	3
Swamp-loosestrife Pond	Natural Vegetation	Natural	3
Sweebay - Swamp Tupelo - (Diamondleaf Oak) Saturated Forest Alliance	Natural Vegetation	Natural	3
Sweebay - Swamp Tupelo - (Diamondleaf Oak) Saturated Forest Alliance [Burned]	Natural Vegetation	Natural	3
Sweebay - Swamp Tupelo - (Diamondleaf Oak) Saturated Forest Alliance [Successional]	Natural Vegetation	Natural	3
Sweetbay - Swampbay Saturated Forest Alliance	Natural Vegetation	Natural	3
Sweetbay - Swampbay Saturated Forest Alliance [Burned]	Natural Vegetation	Natural	3
Sweetbay - Swampbay Saturated Forest Alliance [Successional]	Natural Vegetation	Natural	3
Sweetgum Plantation	Agriculture/Forestry	Ag	3
Temperate Hydric Hammock	Natural Vegetation	Natural/Non-tidal Wetlands	3
Water Oak - Sand Live Oak / Tree Lyonia - Saw Palmetto Forest	Natural Vegetation	Natural	3
Wet Longleaf - Pond Pine Flatwoods	Natural Vegetation	Natural	3
White Oak - Cabagge Palm / Yaupon Forest [Provisional]	Natural Vegetation	Natural	3
Willow Oak - Diamondleaf Oak - Swamp Tupelo - Sweetgum / Switch Cane - Dwarf Palmetto Forest	Natural Vegetation	Natural	3
Xeric Live Oak Hammock	Natural Vegetation	Natural	3
Xeric Oak Scrubland	Natural Vegetation	Natural	3

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