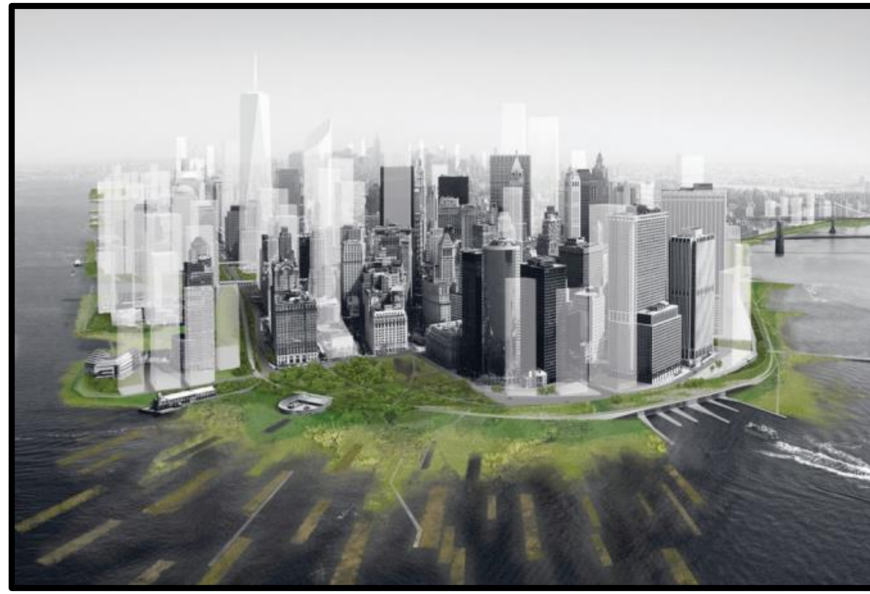
Outline

1. Share the results of the Tidal Saline Wetland Migration study (for the northern Gulf of Mexico)

2. Introduce how this dataset could be used for landscape conservation planning by showing wetland migration in local areas

USGS
science for a changing world



Source: MOMA

Barriers and opportunities for landward migration of tidal saline wetlands with sea-level rise and urbanization

GCPO
Gulf Coastal Plains & Ozarks
Landscape Conservation Cooperative

Gulf Coast Prairie
Landscape Conservation Cooperative

SOUTH ATLANTIC
LANDSCAPE CONSERVATION COOPERATIVE

Peninsular Florida Landscape Conservation Cooperative

Our Team
(at the USGS, Wetland & Aquatic Research Center)

Mike
Osland

Nicholas
Enwright

Kereen
Griffith

USGS

What are tidal saline wetlands?

Salt flats

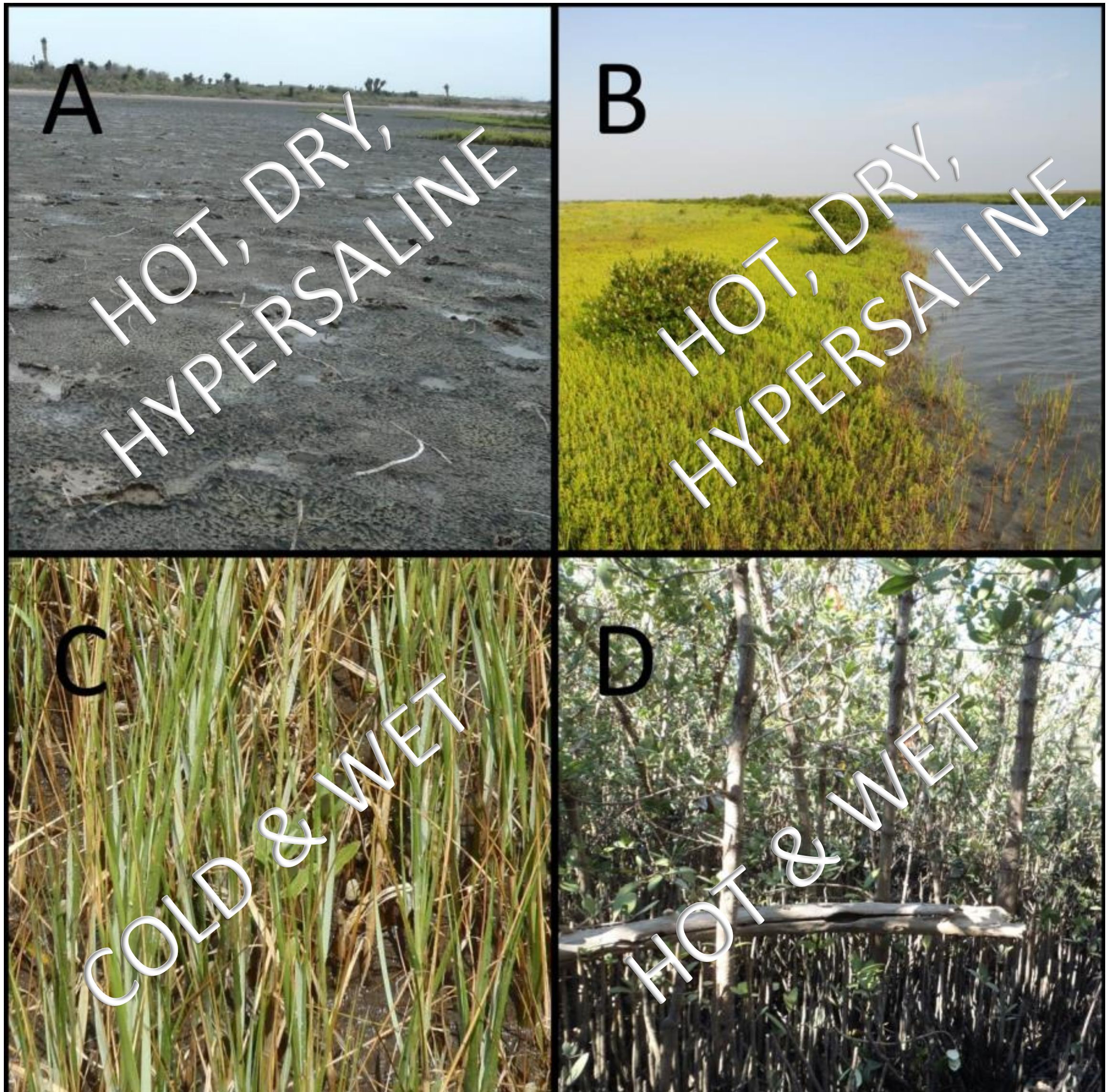
Marshes

Mangroves

Gulf of Mexico coastal saline wetlands are abundant and diverse

Algal mats
(salt flats)

Succulent plants
(salt marshes)



Graminoid plants
(salt marshes)

Mangrove trees and shrubs
(mangrove forests)

Coastal wetlands support many ecosystem goods and services

- Coastal protection/resilience
- Flood mitigation
- Carbon sequestration
- Fish and wildlife habitat
- Nutrient and sediment removal
- Trophic linkages to coastal ecosystems
- Seafood
- Recreation

Source: nps.gov

Source: nola.com

Source: tbep.org

Source: nola.com

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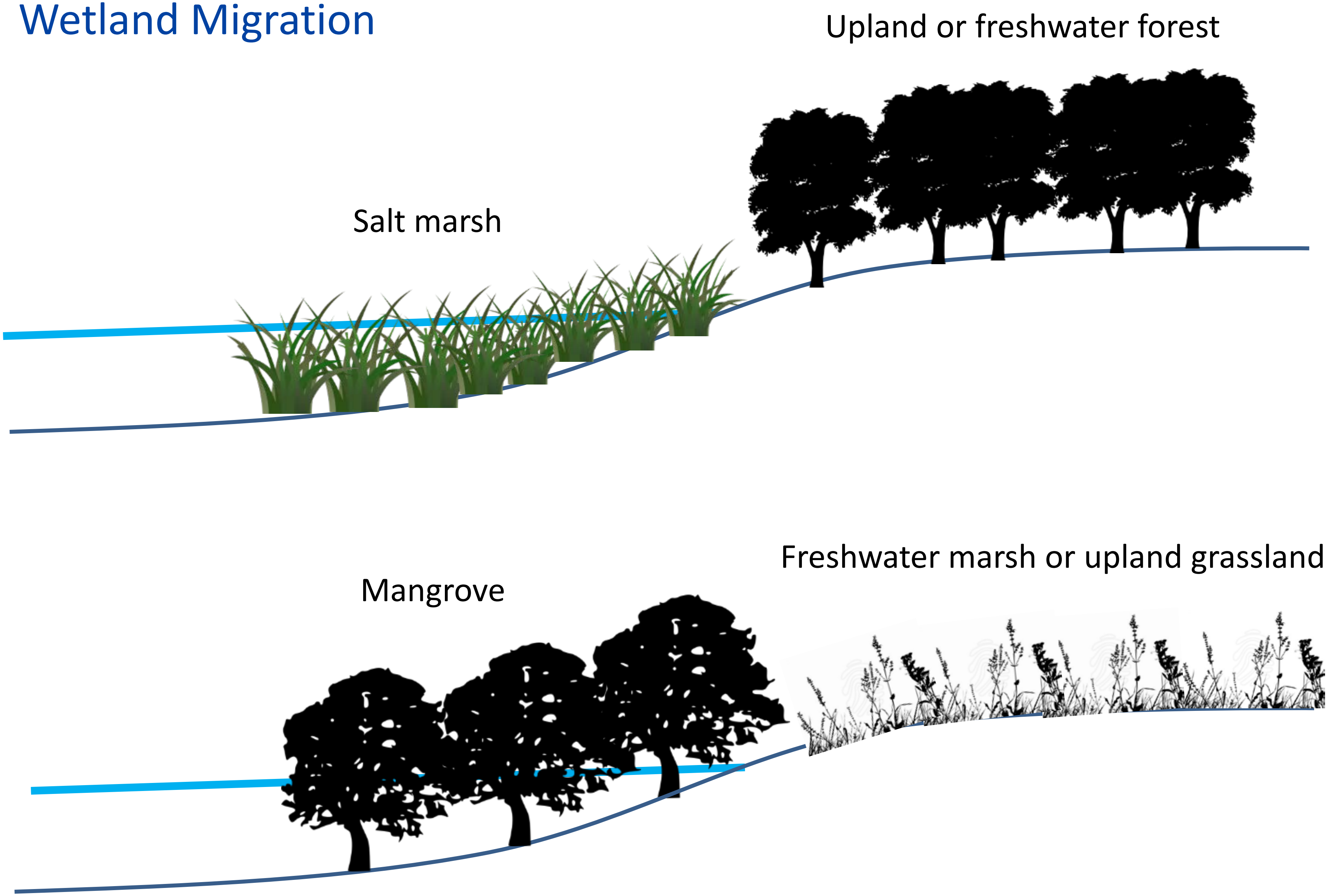
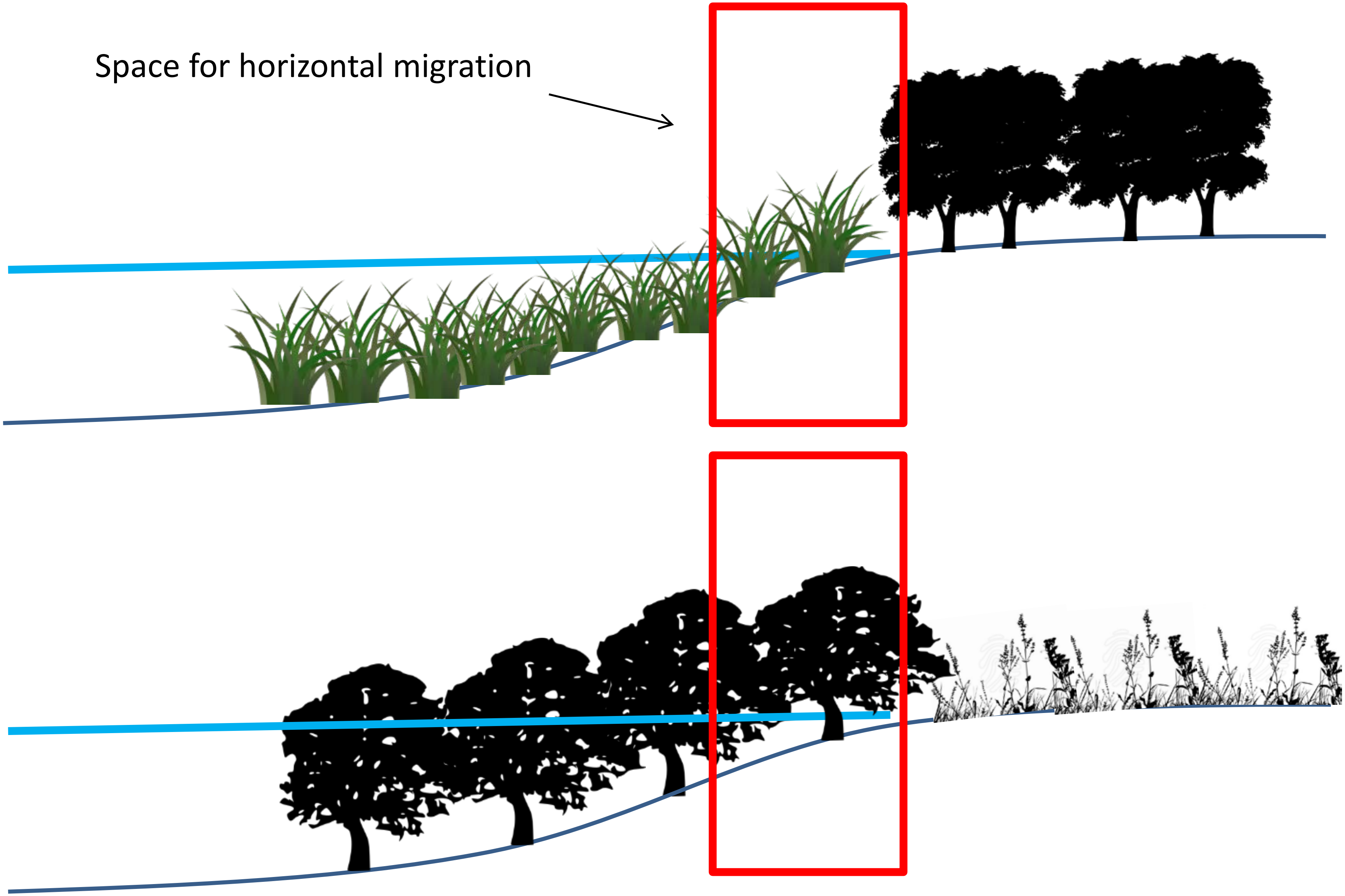
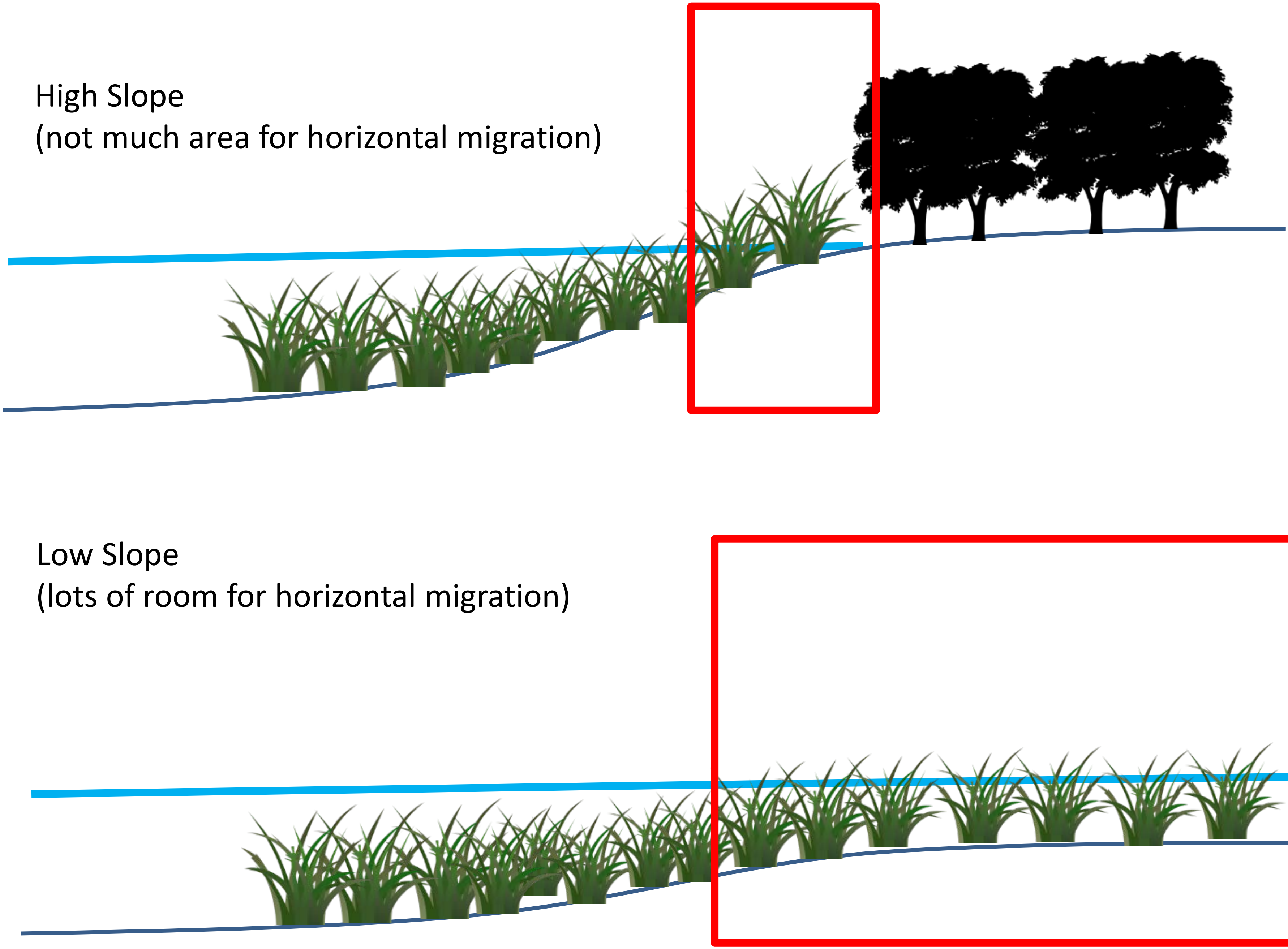
Wetland Migration



Ecosystems and ecotones depend upon climate and landscape position (i.e., it's not the same across the Gulf)



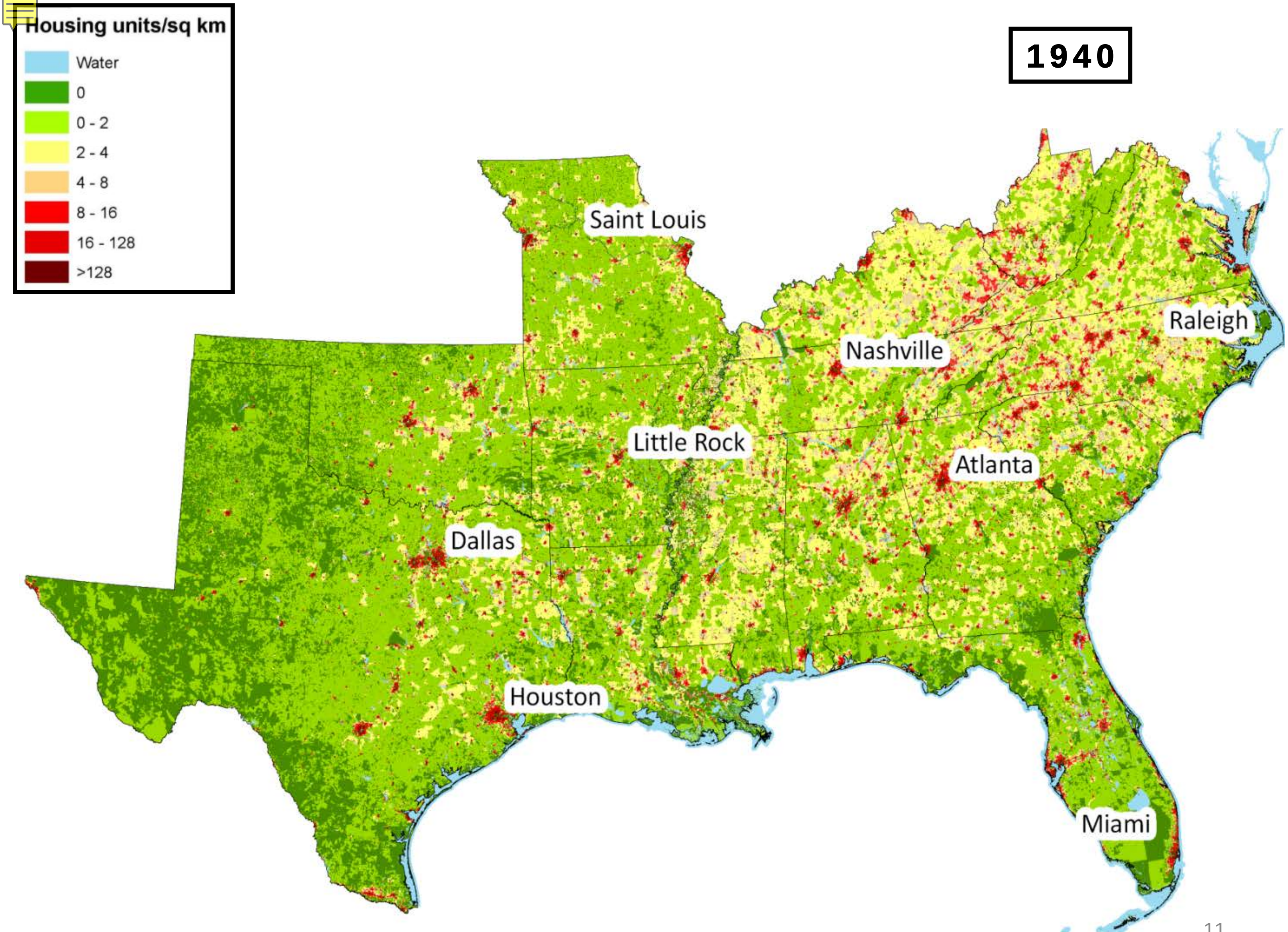
USGS


High Slope
(not much area for horizontal migration)
Low Slope
(lots of room for horizontal migration)

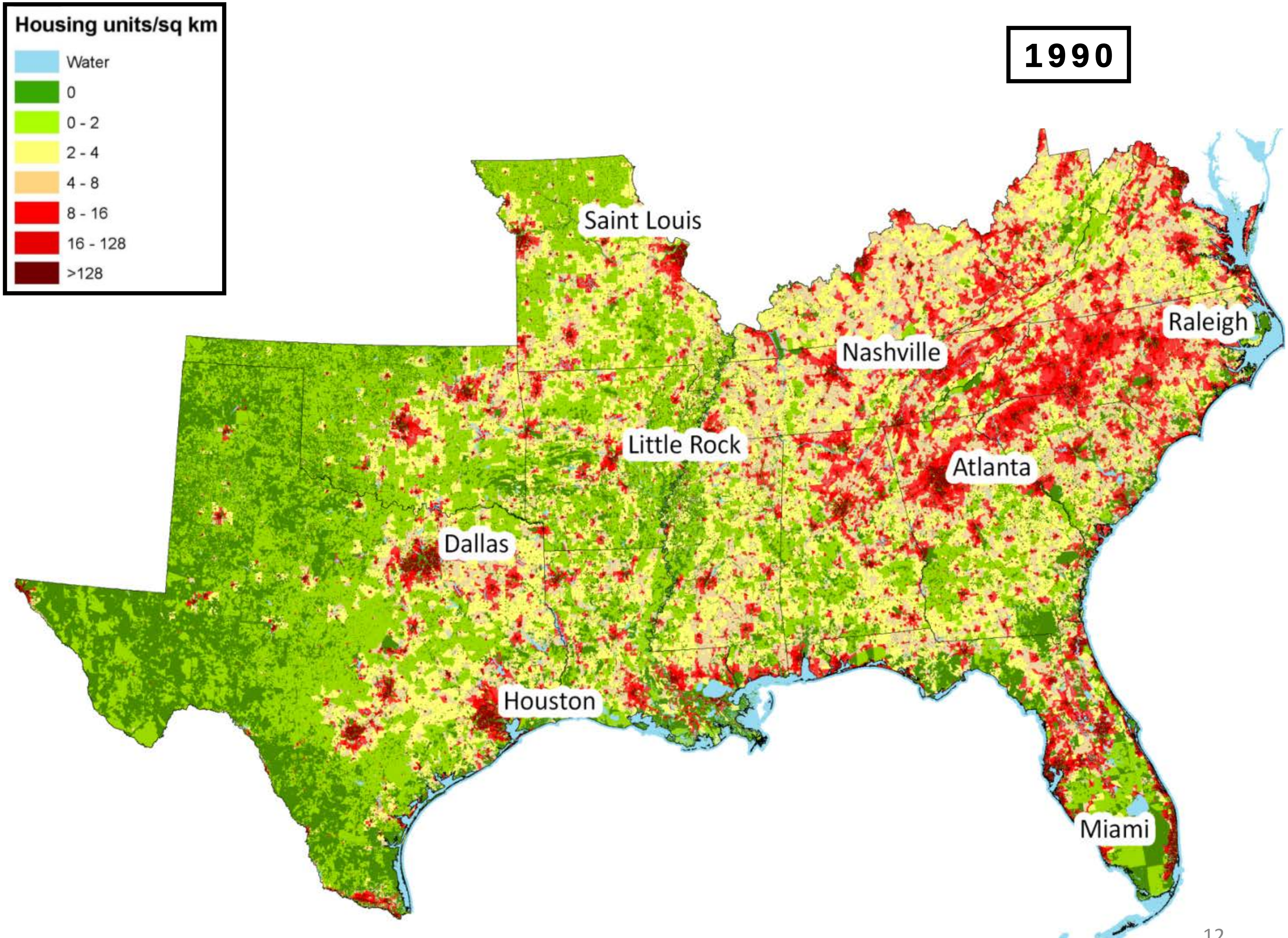
Coastal cities are expanding rapidly

- 39 % of U.S. population lives in Coastal Shoreline Counties
- Expected increase in U.S. Coastal Shoreline Counties (2010-2020):
  - 37 persons/mi^2 vs. 11 persons/mi^2 for U.S. as a whole

Source: U.S. Census Bureau, 2011 as cited on NOAA's State of the Coast



Hammer et al. 2004. *Landscape and Urban Planning*



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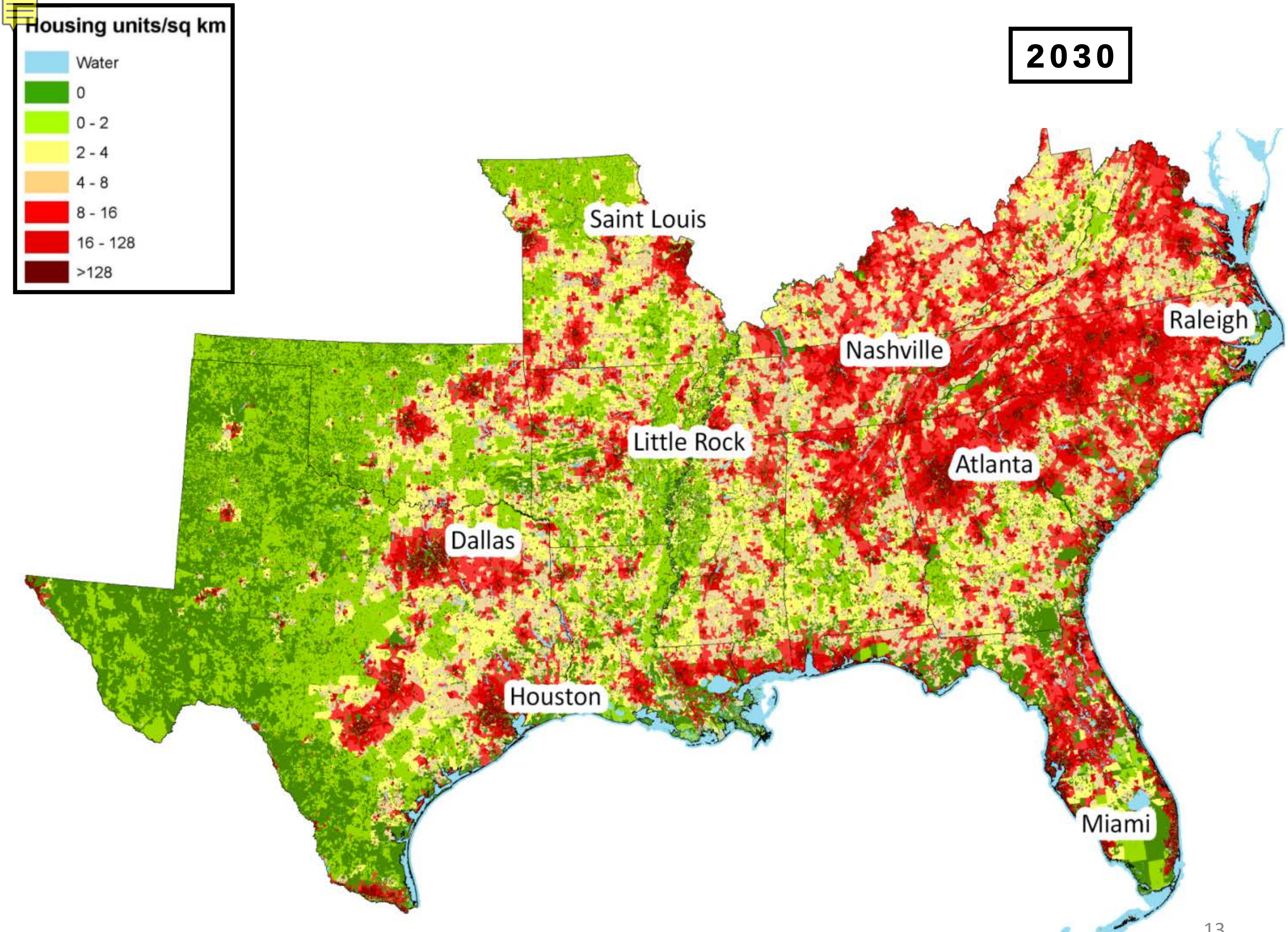

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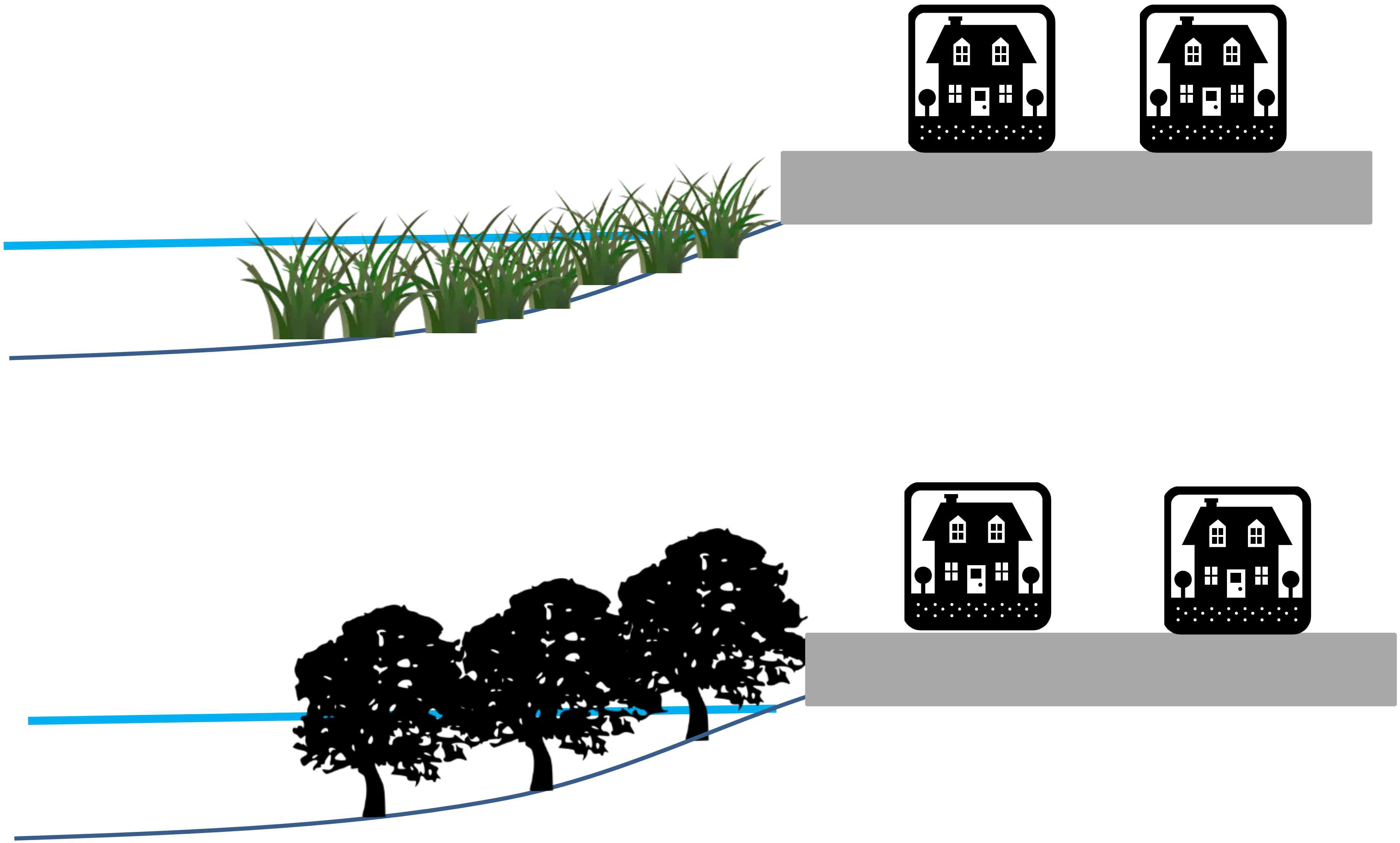

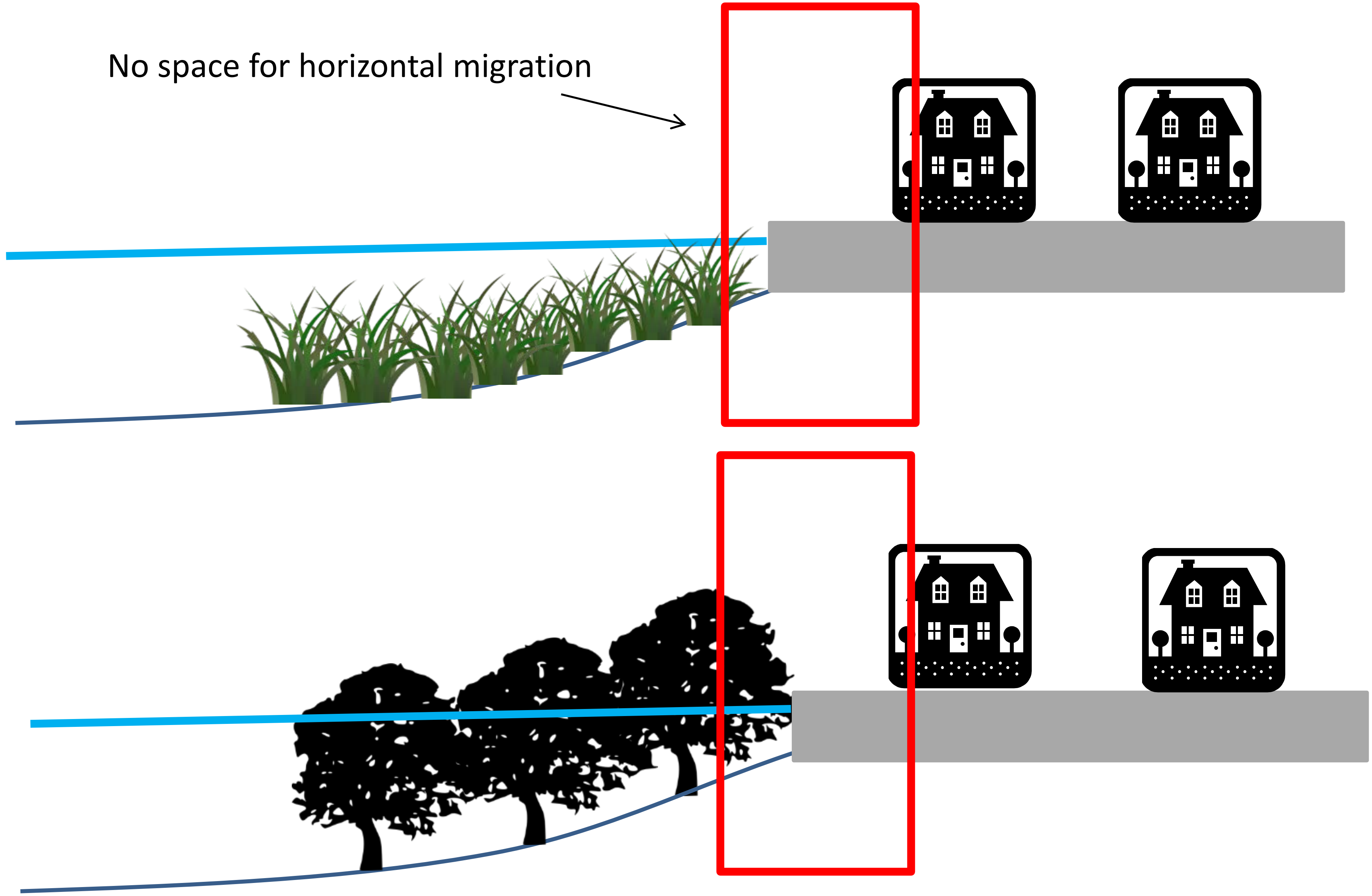

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Key questions for this project

- Where can landward migration of tidal saline wetlands occur?

- Where are there barriers for landward migration of tidal saline wetlands?
  - Barriers: current urban, future urban, leveed lands

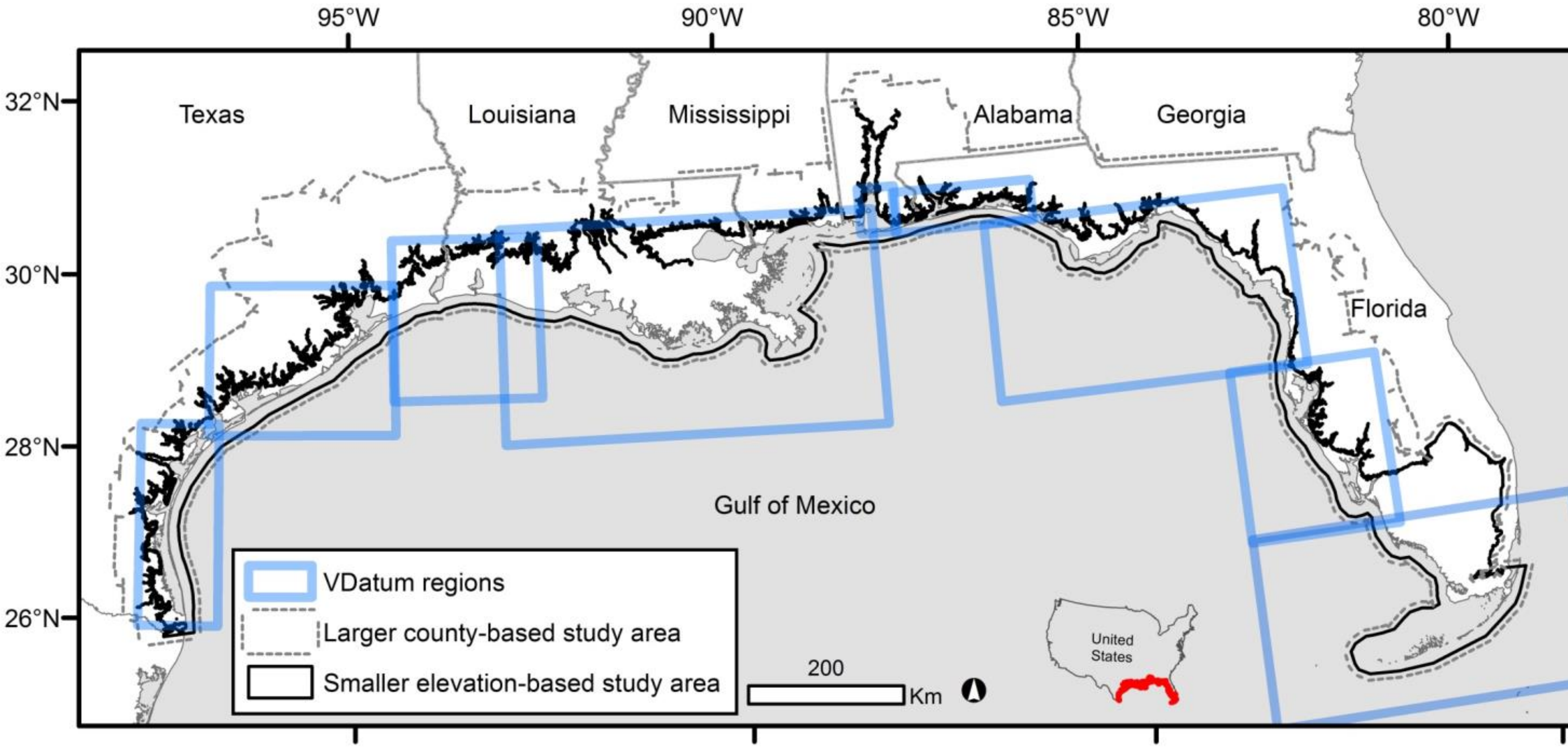
- How can existing protected lands accommodate landward migration of tidal saline wetlands?

USGS

Scenarios and Time Steps

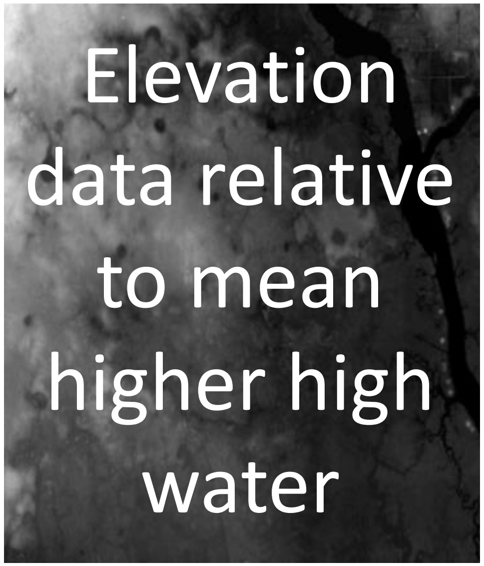
Variables	Values
Scenarios	0.5 m (1.6 ft) 1.0 m (3.3 ft) 1.2 m (3.9 ft) 1.5 m (4.9 ft) 2.0 m (6.6 ft)
Time steps	Current 2030 2040 2050 2060 2100

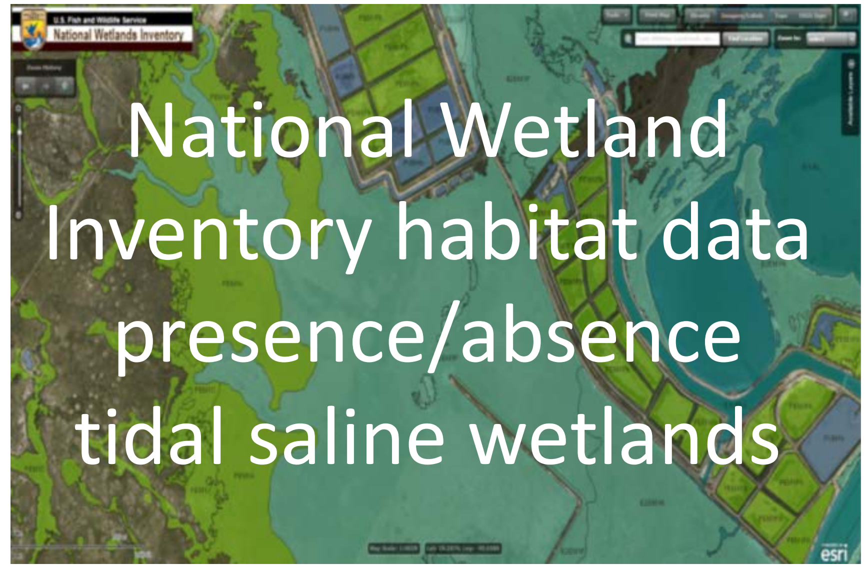
Study area



95°W
90°W
85°W
80°W
32°N
30°N
28°N
26°N
Texas
Louisiana
Mississippi
Alabama
Georgia
Florida
Gulf of Mexico
VDatum regions
Larger county-based study area
Smaller elevation-based study area
200
Km
United States

Determining the TSW Boundary





1. Current tidal saline wetlands
2. Map future wetlands by adding the sea-level rise increment for each time step-scenario combination

Future urban growth

SLEUTH

Urban-growth model used by Terando et al. 2014 (PLOS ONE) for the southeastern United States

OPEN ACCESS Freely available online

PLOS | ONE

The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S.

Adam J. Terando[1,2*], Jennifer Costanza[2], Curtis Belyea[2], Robert R. Dunn[3], Alexa McKerrow[2,4], Jaime A. Collazo[2,5]

1 Southeast Climate Science Center, US Geological Survey, Raleigh, North Carolina, United States of America, 2 Department of Applied Ecology, North Carolina State University, Raleigh, North Carolina, United States of America, 3 Department of Biological Sciences, North Carolina State University, Raleigh, North Carolina, United States of America, 4 Core Science Analytics and Synthesis, US Geological Survey, Raleigh, North Carolina, United States of America, 5 U.S. Geological Survey, North Carolina Cooperative Fish and Wildlife Research Unit, North Carolina State University, Raleigh, North Carolina, United States of America

Abstract

The future health of ecosystems is arguably as dependent on urban sprawl as it is on human-caused climatic warming. Urban sprawl strongly impacts the urban ecosystems it creates and the natural and agro-ecosystems that it displaces and fragments. Here, we project urban sprawl changes for the next 50 years for the fast-growing Southeast U.S. Previous studies have focused on modeling population density, but the urban extent is arguably as important as population density per se in terms of its ecological and conservation impacts. We develop simulations using the SLEUTH urban growth model that complement population-driven models but focus on spatial pattern and extent. To better capture the reach of low-density suburban development, we extend the capabilities of SLEUTH by incorporating street-network information. Our simulations point to a future in which the extent of urbanization in the Southeast is projected to increase by 101% to 192%. Our results highlight areas where ecosystem fragmentation is likely, and serve as a benchmark to explore the challenging tradeoffs between ecosystem health, economic growth and cultural desires.

Citation: Terando AJ, Costanza J, Belyea C, Dunn RR, McKerrow A, et al. (2014) The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S.. PLoS ONE 9(7): e102261. doi:10.1371/journal.pone.0102261

Editor: Craig A. Layman, North Carolina State University, United States of America

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Data Availability: The authors confirm that all data underlying the findings are fully available without restriction. Data are in the USGS Geo Data Portal for public access and are available with the DOI: http://dx.doi.org/10.5066/F7BP00SX.

Funding: This research was supported by the US Geological Survey (http://www.usgs.gov/) through the National Climate Change and Wildlife Science Center (https://nccwsc.usgs.gov/) and the Dept of Interior Southeast Climate Science Center (http://globalchange.ncsu.edu/secsc/) through grant agreement G11AC20524. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

* Email: aterando@usgs.gov

Introduction

Cities are expanding, and as they do urban sprawl–low-density urban development outside the urban core–is expanding even more rapidly. In some regions, expansion of suburban habitats as a result of shifts to automobile-dependent living has led to increases in the urban footprint even where populations have not shown large increases [1]. Urban sprawl increases the connectivity among urban habitats while simultaneously fragmenting non-urban habitats such as forests and grasslands. These changes have a variety of effects on species and ecosystems, including impacts to water pollution, disturbance dynamics, local climate, and predator-prey relationships [2–5]. Urban sprawl will also, almost certainly, influence the ability of species to respond to climate change, in as much as it creates barriers to the movement of species that cannot survive in cities and corridors for those who can [6]. Knowledge about the potential future character of urban sprawl is thus useful to a variety of stakeholders, including resource managers, conservation organizations, and urban planners.

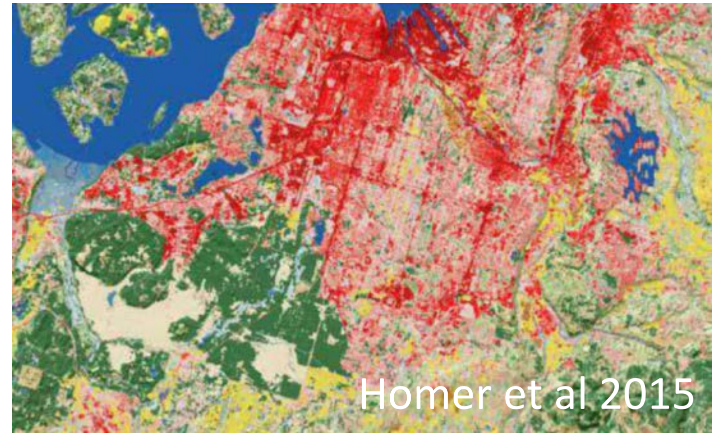
Any hope of integrating the effects of urbanization into management plans (whether for humans or wildlife), will depend on projections of urban sprawl. Such projections are typically generated using urban-growth models. The challenge is how to generate projections of urbanization that are robust enough to inform management priorities, decisions, and actions. In this regard, the challenge is similar to that faced when projecting climate change. In both cases, human actions taking place over decades will determine the outcome, and individual actions (global greenhouse gas emissions in the case of climate change; population growth, automobile dependency, and housing preferences in the case of urban growth) are difficult to predict on the time-scales of interest to decision-makers. In other words, the future as it relates to human actions has more uncertainty than what can be realistically quantified in an individual model.

A more cautious approach is to define scenarios that represent one or more particular kinds of futures, and then construct models to simulate the consequences of each scenario. For fast growing regions such as the Southeast US, the most relevant scenario for conservation and adaptation planning is the "business-as-usual" (BAU) scenario in which the net effect of growth is in line with that which has occurred in the past. While recent "Smart-Growth" initiatives that promote more intensive development and a return to a strong urban core are gaining popularity, this BAU scenario is still reflective of the primary development model. And without significant changes to the status quo, this type of growth will continue. Decision makers can use this information to see how the

Current urban and current leveed

Current Urban

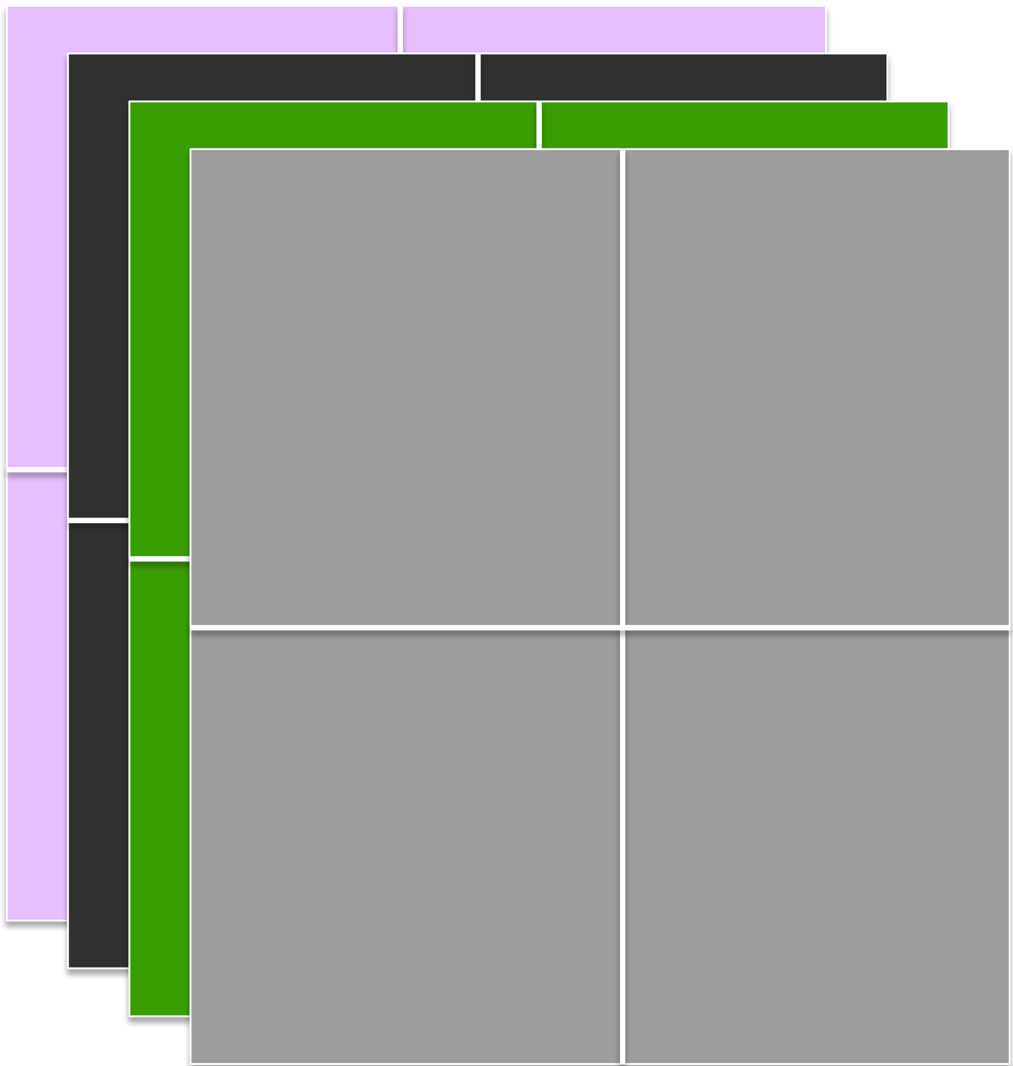
Areas identified as current urban in SLEUTH and the 2011 USGS National Land Cover Database



Current Leveed

U.S. Army Corps of Engineers National Levee Database and other local data

Wetland Migration Corridors



Future tidal saline wetlands

+

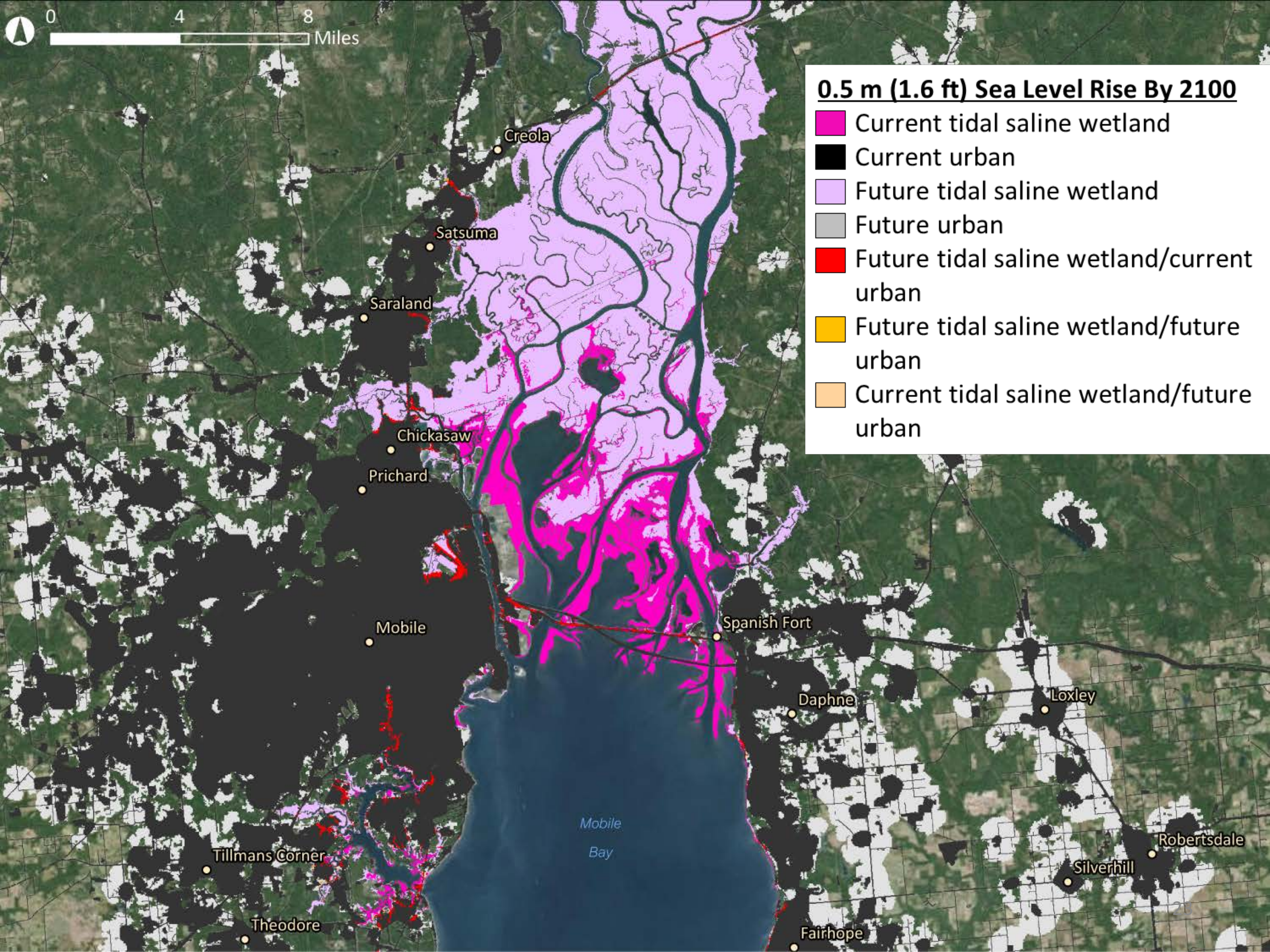
Current urban

+

Current leveed

+

Future urban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0.5 m (1.6 ft) Sea Level Rise By 2100
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Future tidal saline wetland/current urban
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Current tidal saline wetland/future urban
Creola
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Saraland
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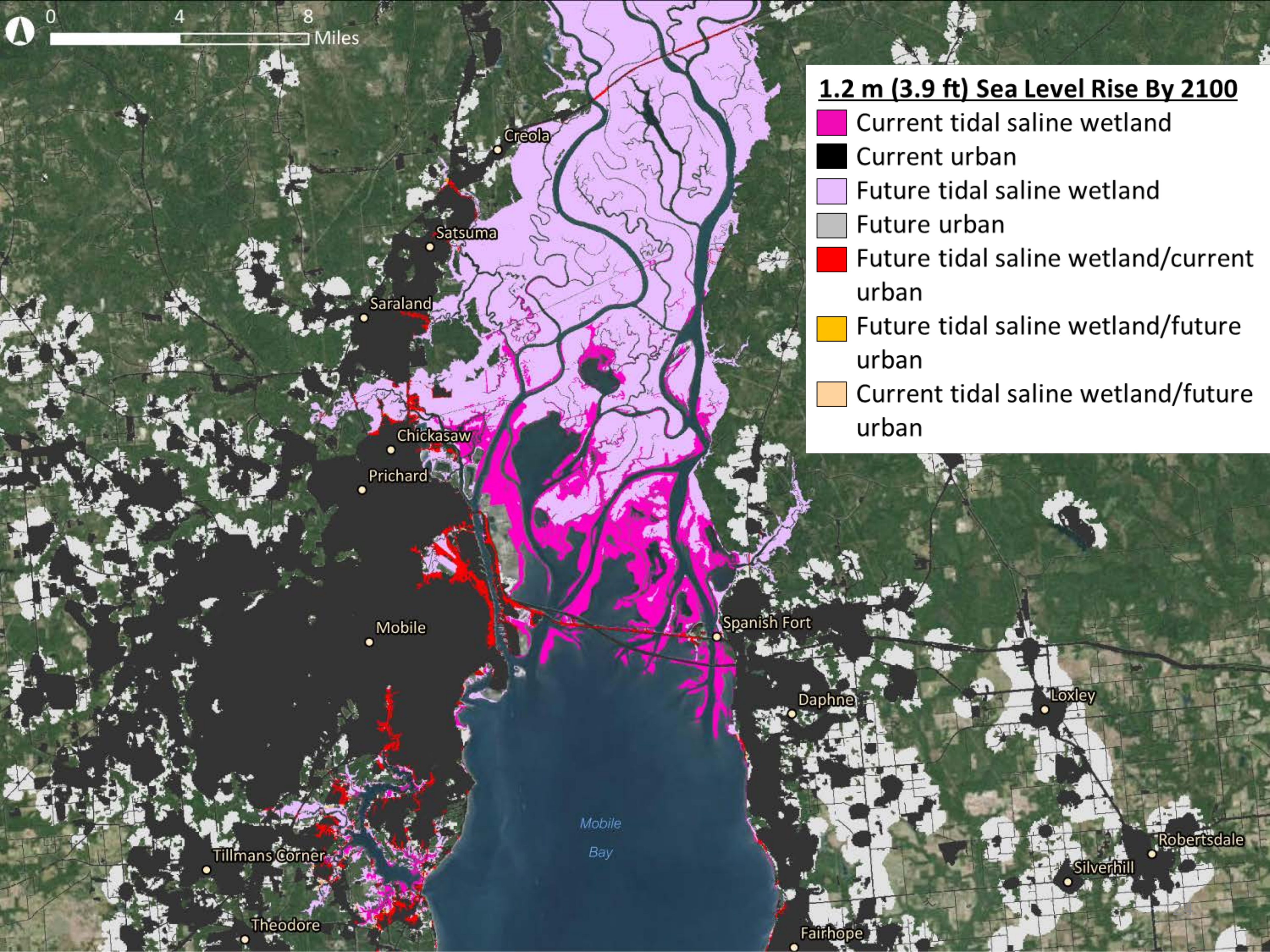
Silverhill
Tillmans Corner
Theodore
Fairhope



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1.2 m (3.9 ft) Sea Level Rise By 2100
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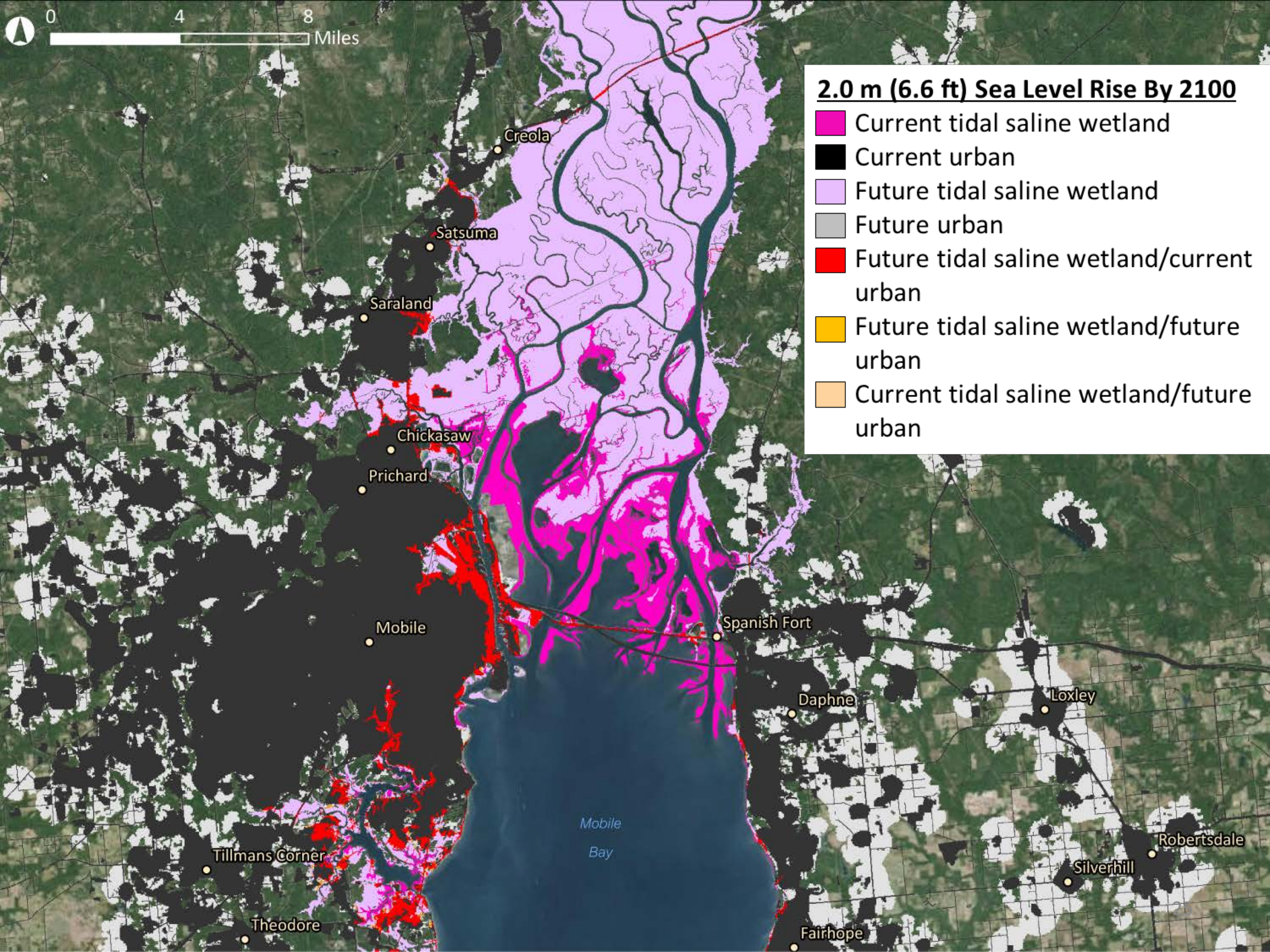
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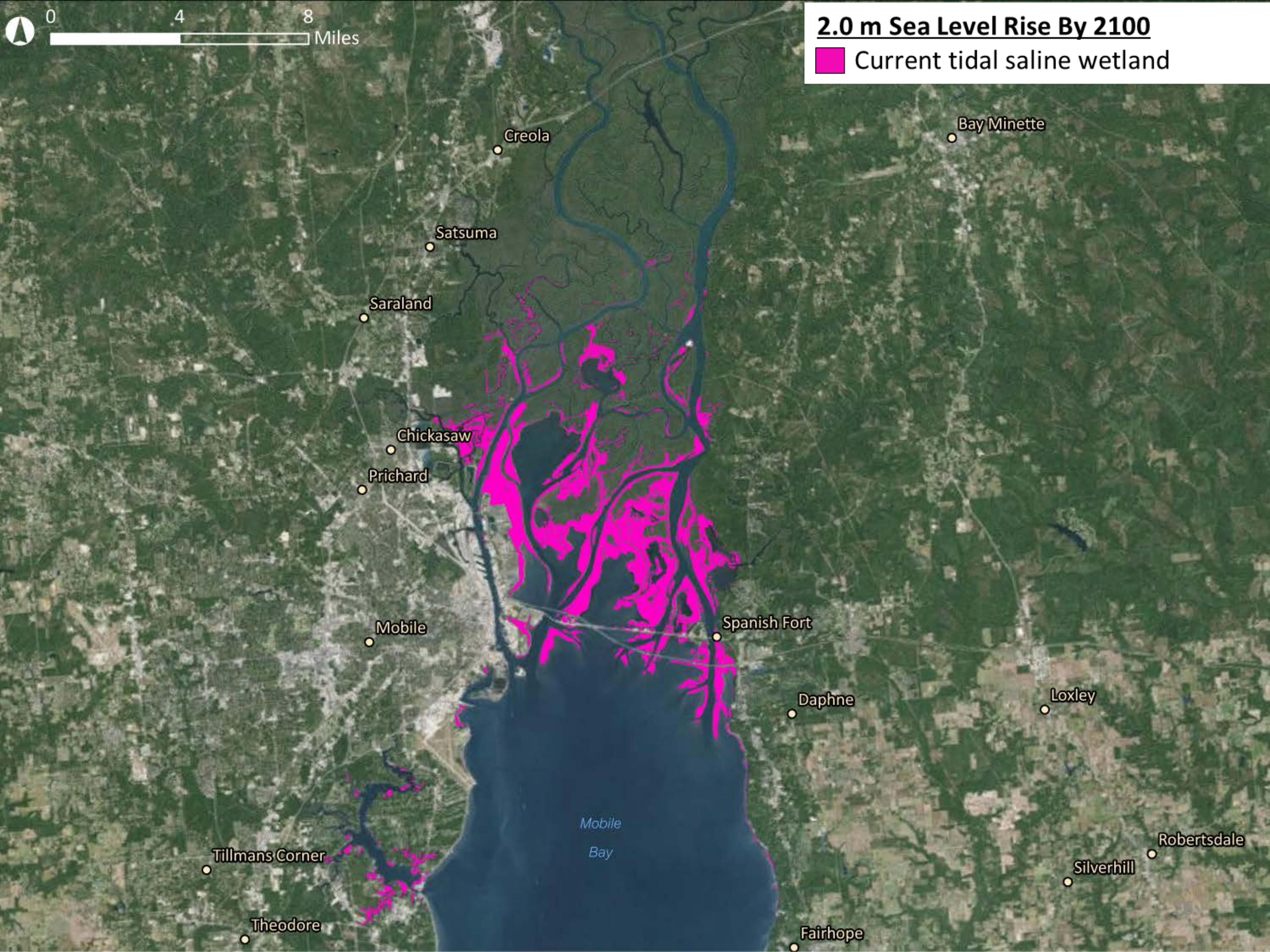

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Robertsdale
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2.0 m Sea Level Rise By 2100
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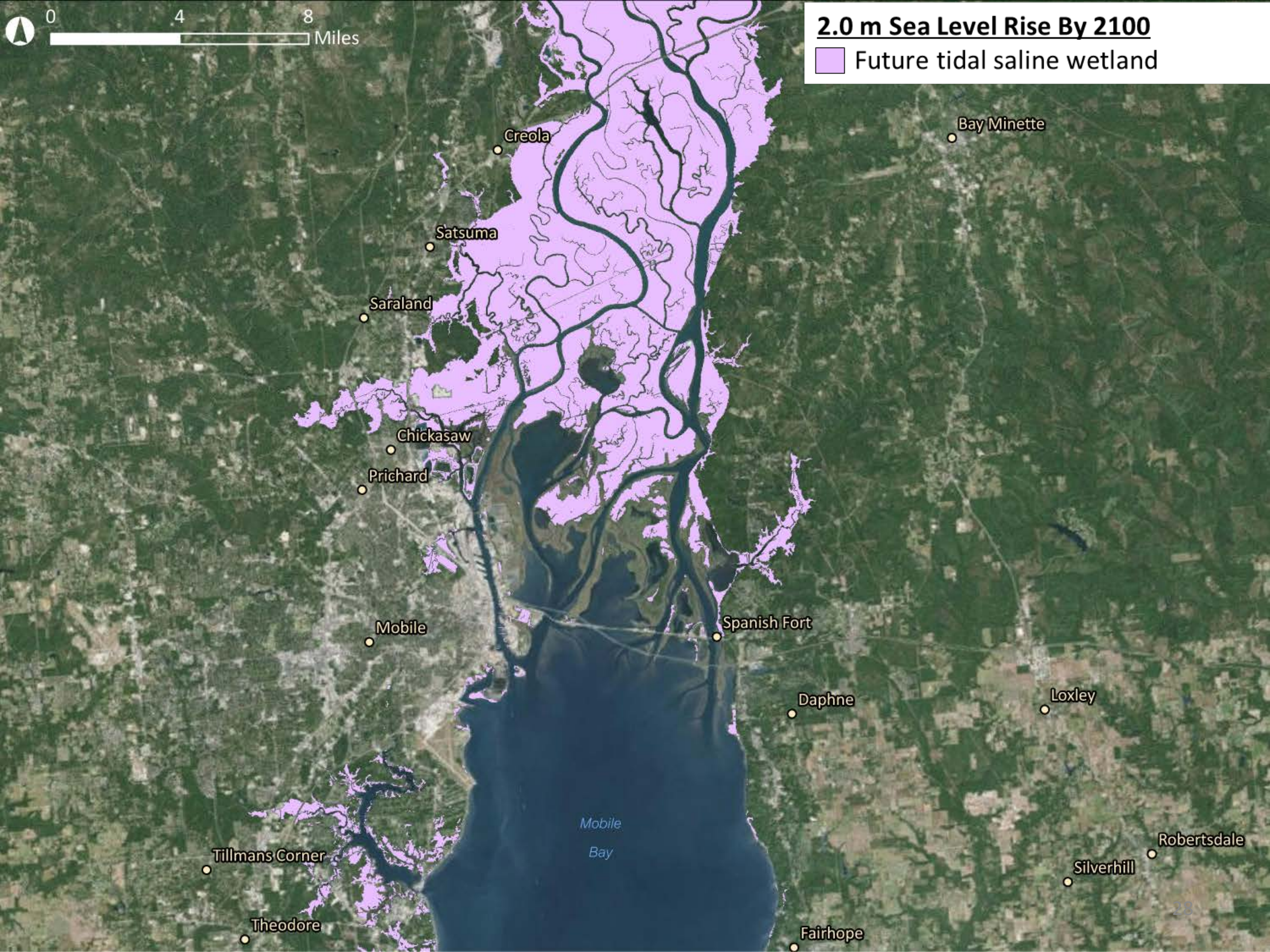

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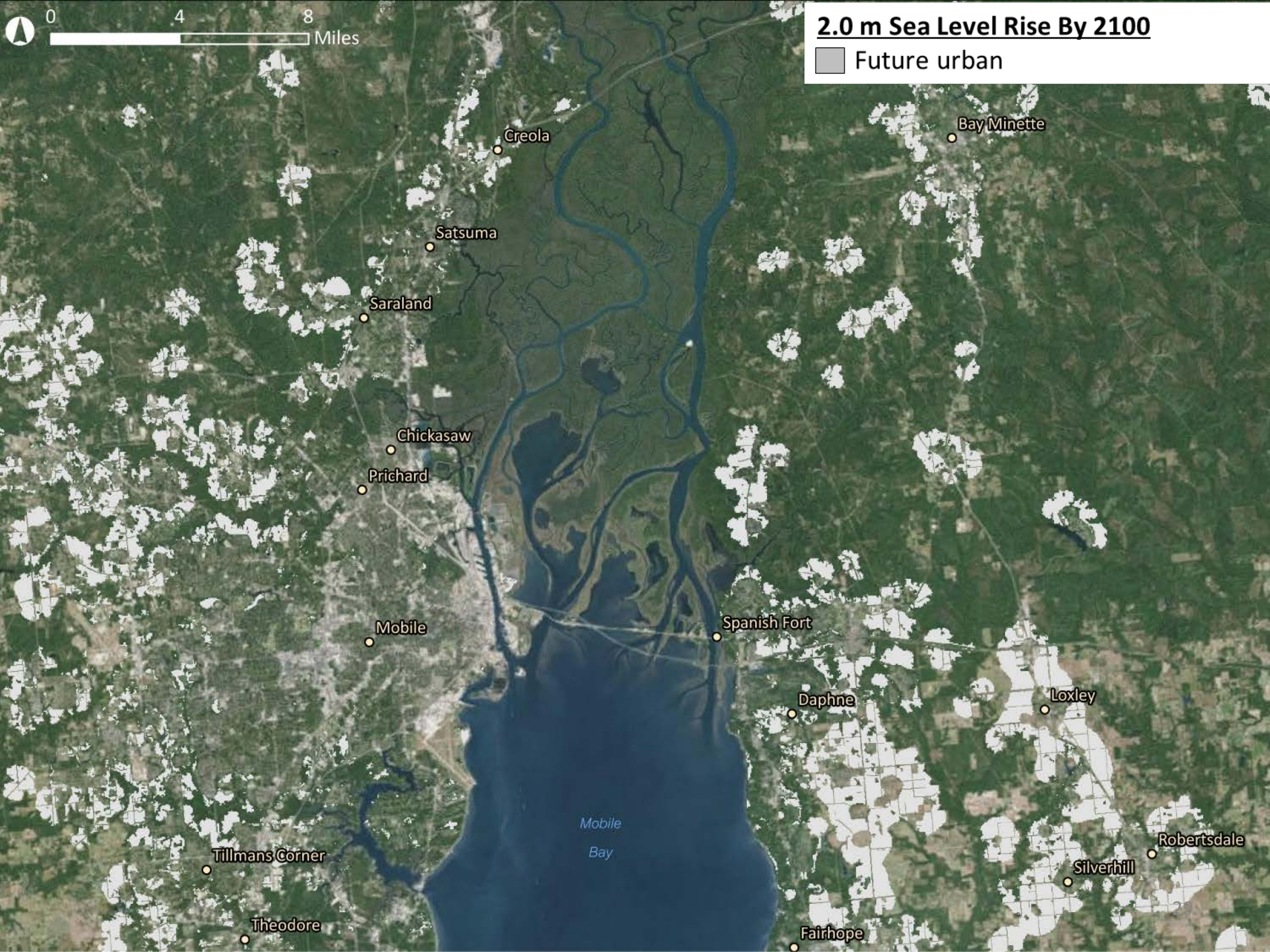
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2.0 m Sea Level Rise By 2100
Future tidal saline wetland/current urban
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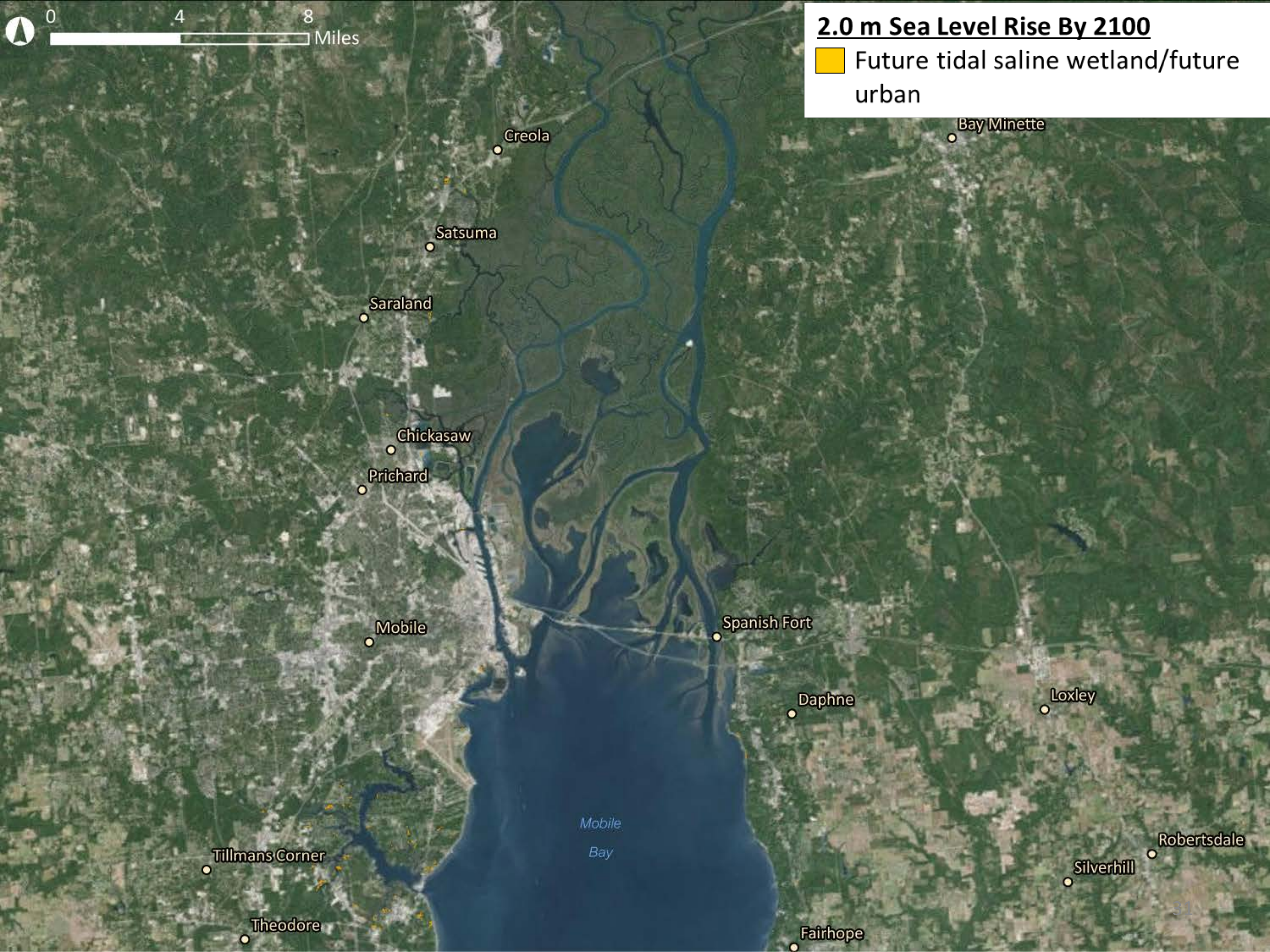

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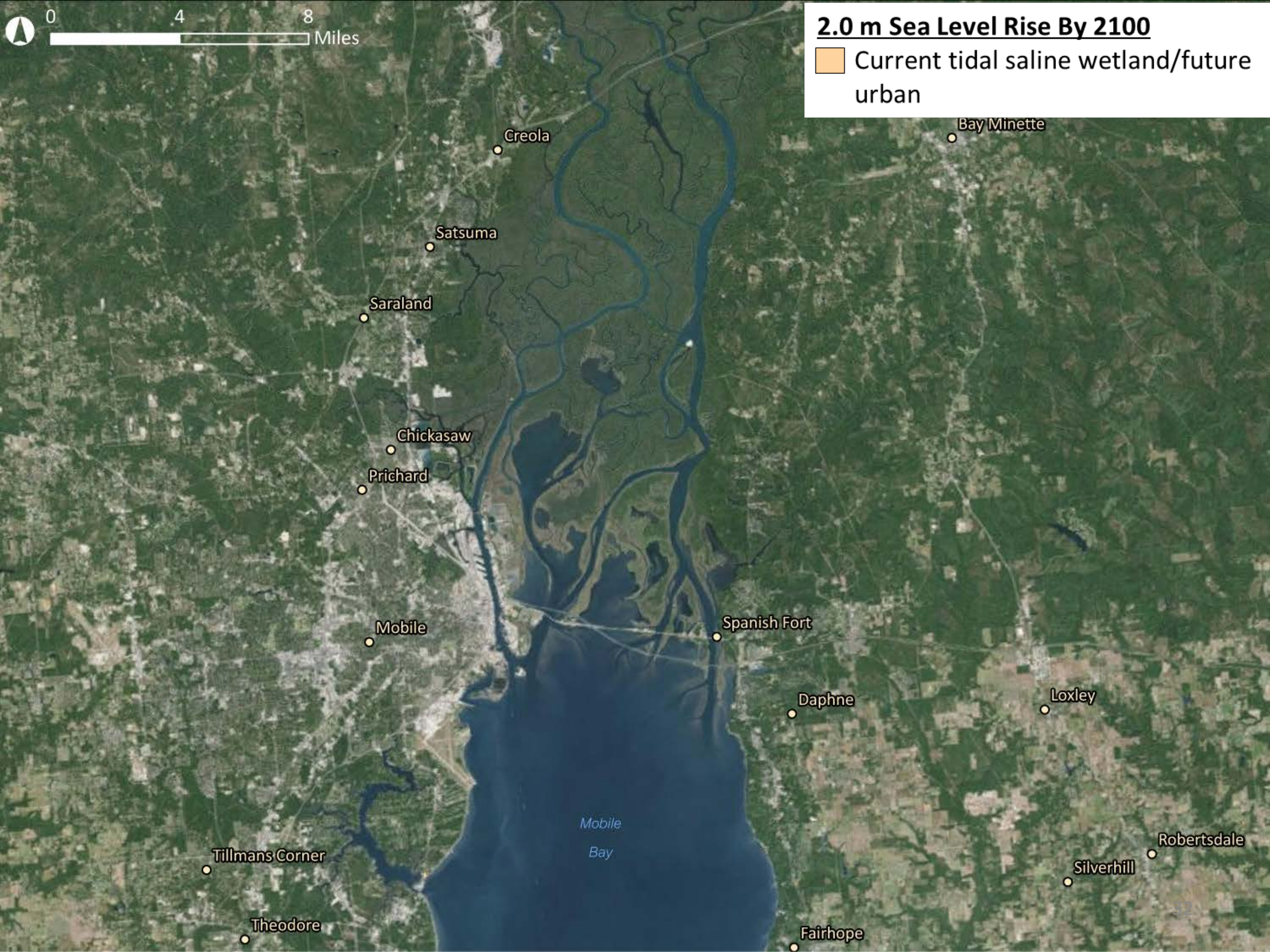
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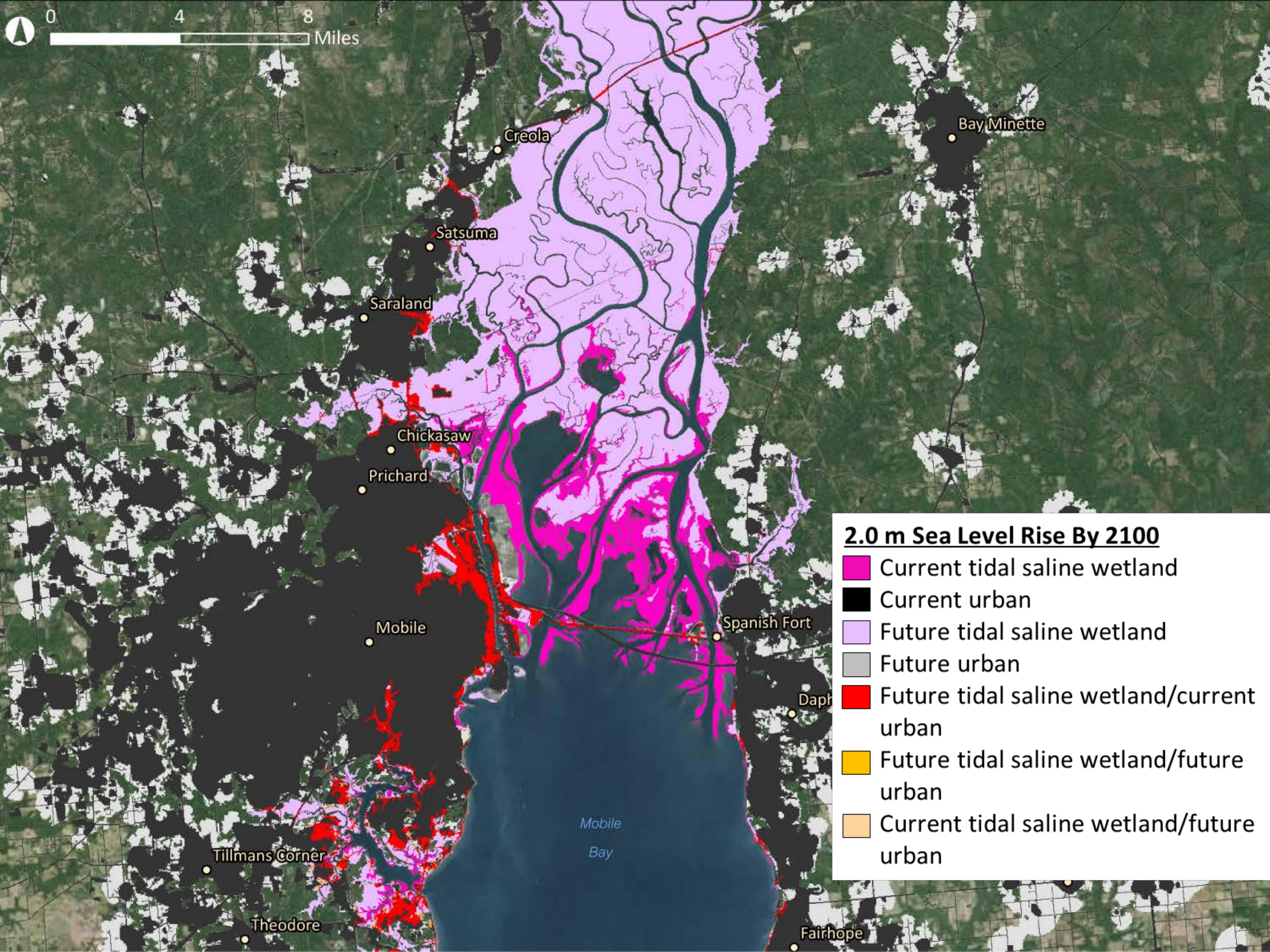
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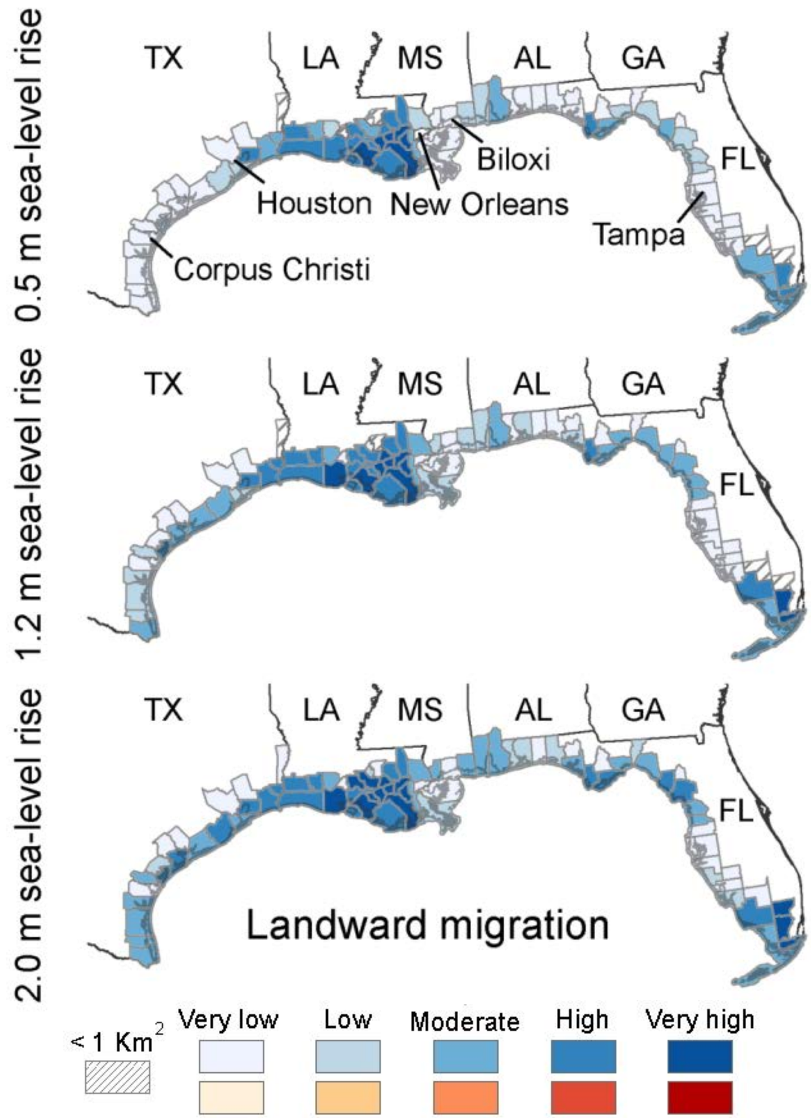
Current urban
Future tidal saline wetland
Future urban
Future tidal saline wetland/current urban
Future tidal saline wetland/future urban
Current tidal saline wetland/future urban

Where is area available for landward wetland migration?



Enwright et al. 2016. *Frontiers in Ecology and the Environment*

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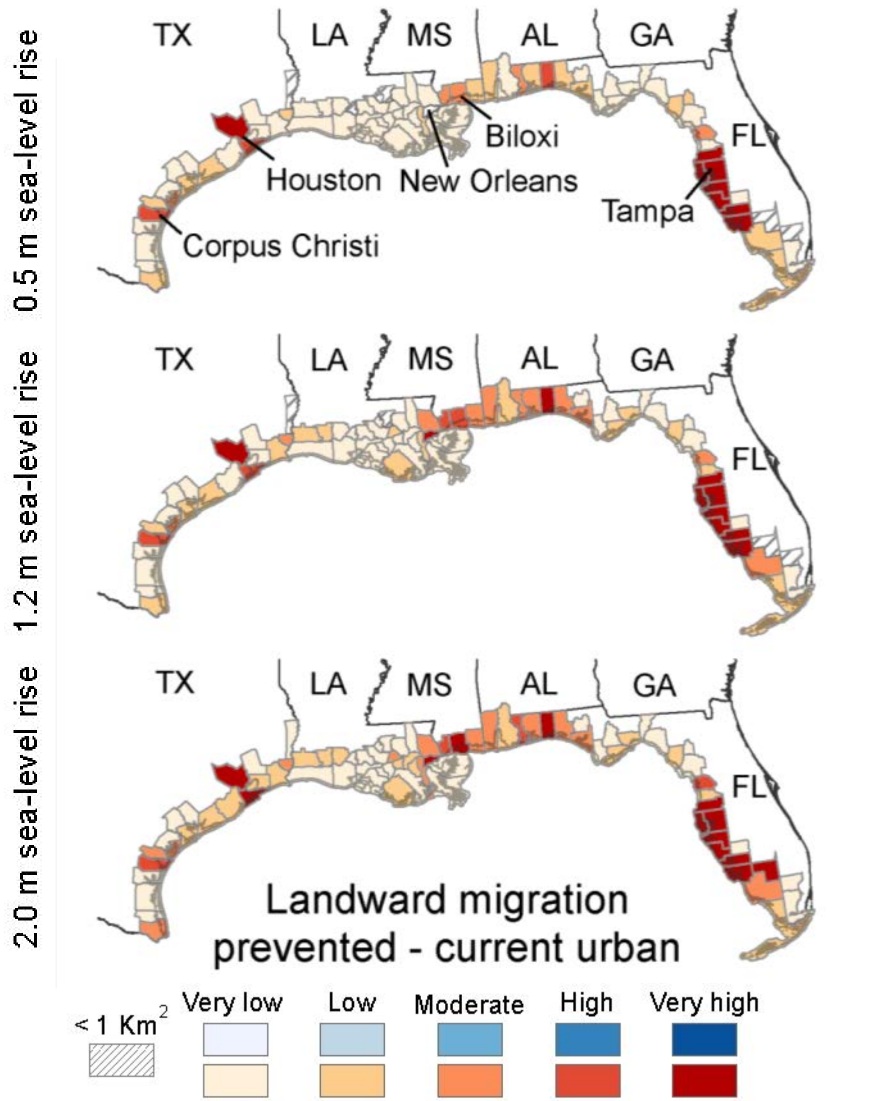
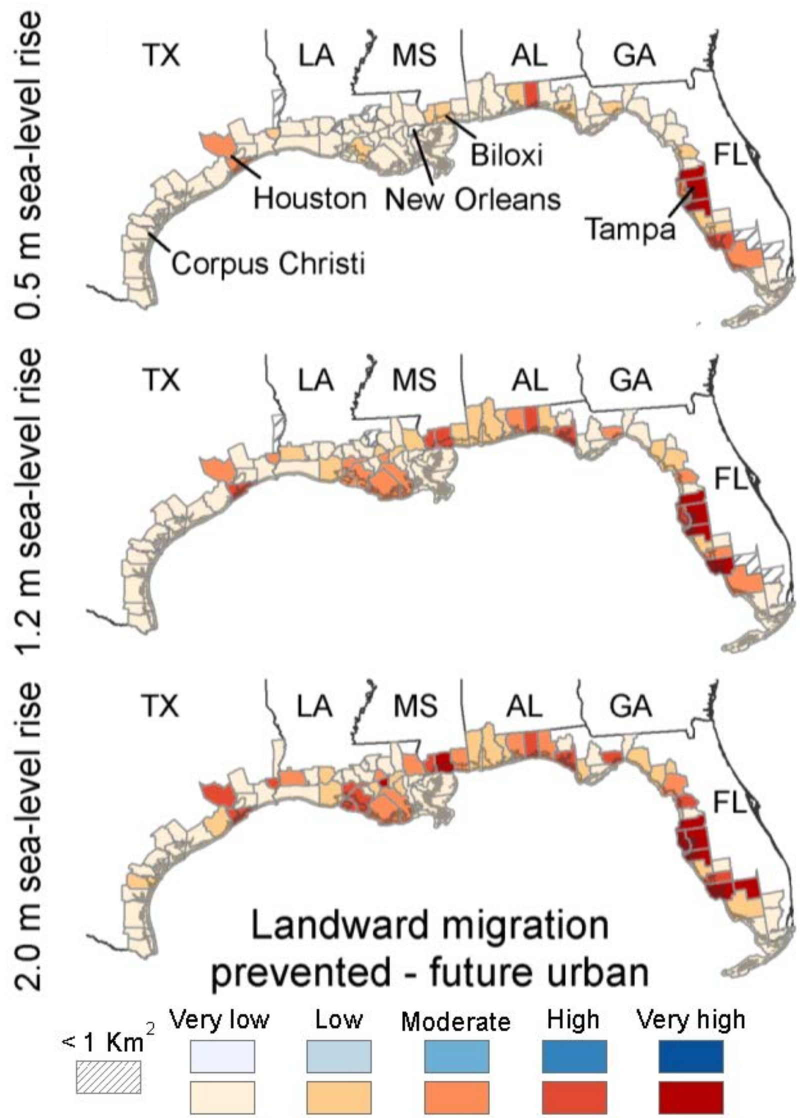
Where will landward wetland migration be prevented by current urban barriers?



Enwright et al. 2016. *Frontiers in Ecology and the Environment*

USGS

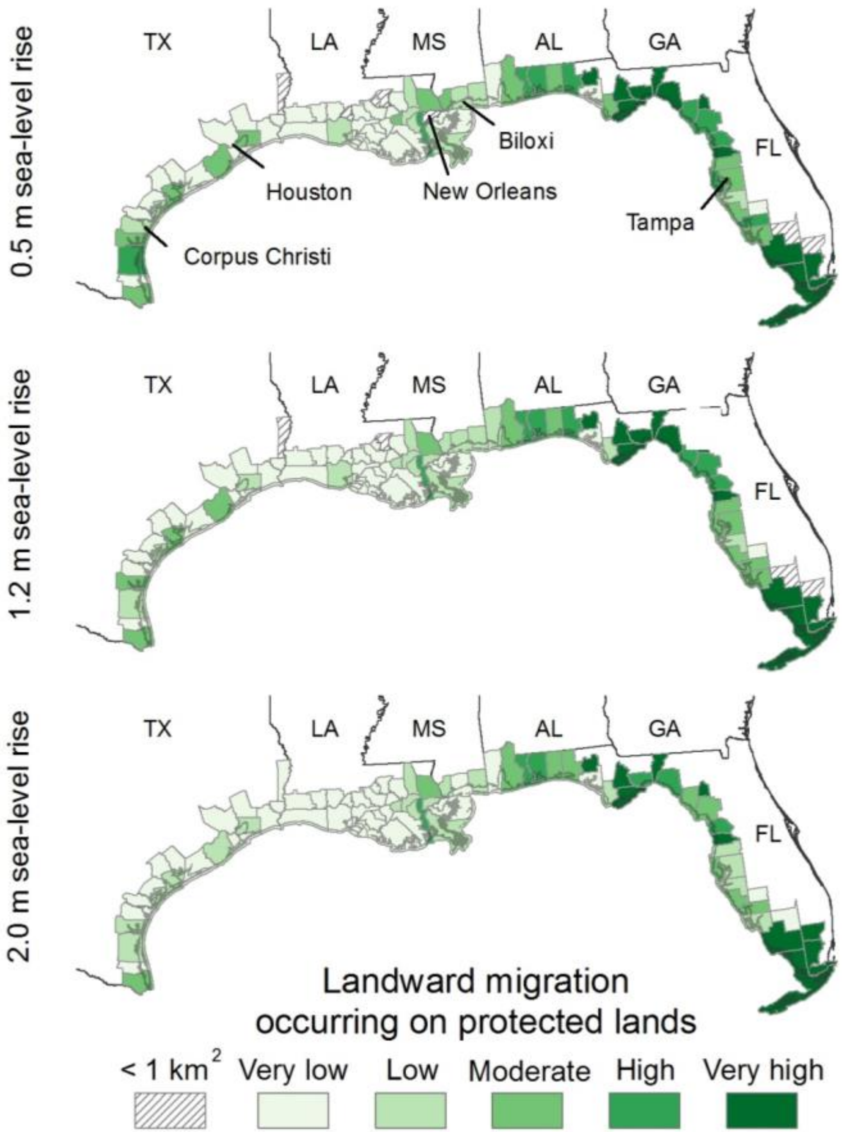
Where will landward wetland migration be prevented by future urban barriers?



Enwright et al. 2016.
Frontiers in Ecology and the Environment

USGS

Where will landward wetland migration occur on protected lands?



USGS

Enwright et al. 2016. *Frontiers in Ecology and the Environment*

Products

1. **Data Series Report:** Enwright, N.M., Griffith, K.T., and Osland, M.J., 2015, Incorporating future change into current conservation planning—Evaluating tidal saline wetland migration along the U.S. Gulf of Mexico coast under alternative sea-level rise and urbanization scenarios: U.S. Geological Survey Data Series 969, http://dx.doi.org/10.3133/ds969

2. **Data available for download** via Science Base: https://www.sciencebase.gov/catalog/item/55f742a8e4b0477df11c0a2b

3. **Data available for viewing** in a map viewer via the LCC Conservation Planning Atlas: http://gcpolcc.databasin.org/galleries/bbfff0152bb14aa5aea5012d02f3156f

4. **Journal Article:** Enwright, N.M., Griffith, K.T., and Osland, M.J. 2016. Barriers and opportunities for landward migration of coastal wetlands with sea-level rise. *Frontiers in Ecology and the Environment* 14:307-316.

Summary

- Where can landward migration of tidal saline wetlands occur?
  - Louisiana, southern Florida, southern TX under higher SLR scenarios

- Where are there barriers for landward migration of tidal saline wetlands?
  - Urban development: coast from Tampa to Fort Myers, Houston/Galveston, Corpus Christi
  - Levees: Louisiana, southern Florida, eastern Texas
  - Topographic: Florida panhandle, south central FL, MS, southern TX

- How can existing protected lands accommodate landward migration of tidal saline wetlands?
  - Everglades, migration in LA on private lands

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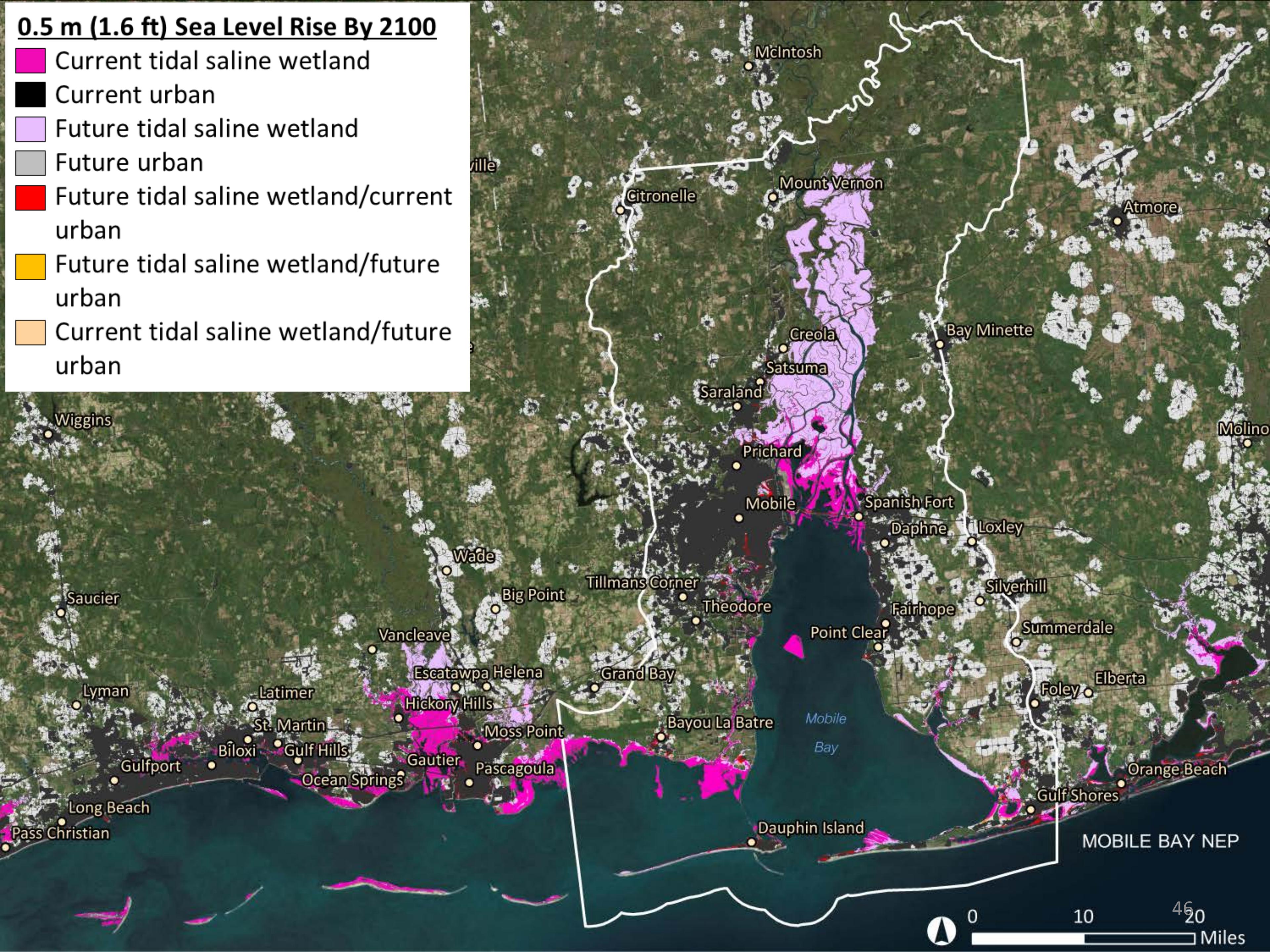
Conclusions

- Highlighted areas where coastal wetland migration is abundant and where there are barriers to migration
- Predict where wetlands will be able to travel in order to inform landscape conservation plans
- Increase the ability of coastal wetlands to adapt to rising sea levels

Wetland Migration in Local Areas

Mobile Bay NEP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Future tidal saline wetland
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McIntosh
Mount Vernon
Citronelle
Atmore
Bay Minette
Creola
Satsuma
Saraland
Wiggins
Molino
Prichard
Mobile
Spanish Fort
Daphne
Loxley
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Big Point
Saucier
Theodore
Silverhill
Fairhope
Summerdale
Vancleave
Point Clear
Escatawpa
Helena
Grand Bay
Elberta
Foley
Lyman
Latimer
Hickory Hills
St. Martin
Bayou La Batre
Moss Point
Mobile Bay
Biloxi
Gulf Hills
Gulfport
Gautier
Pascagoula
Ocean Springs
Orange Beach
Gulf Shores
Long Beach
Pass Christian
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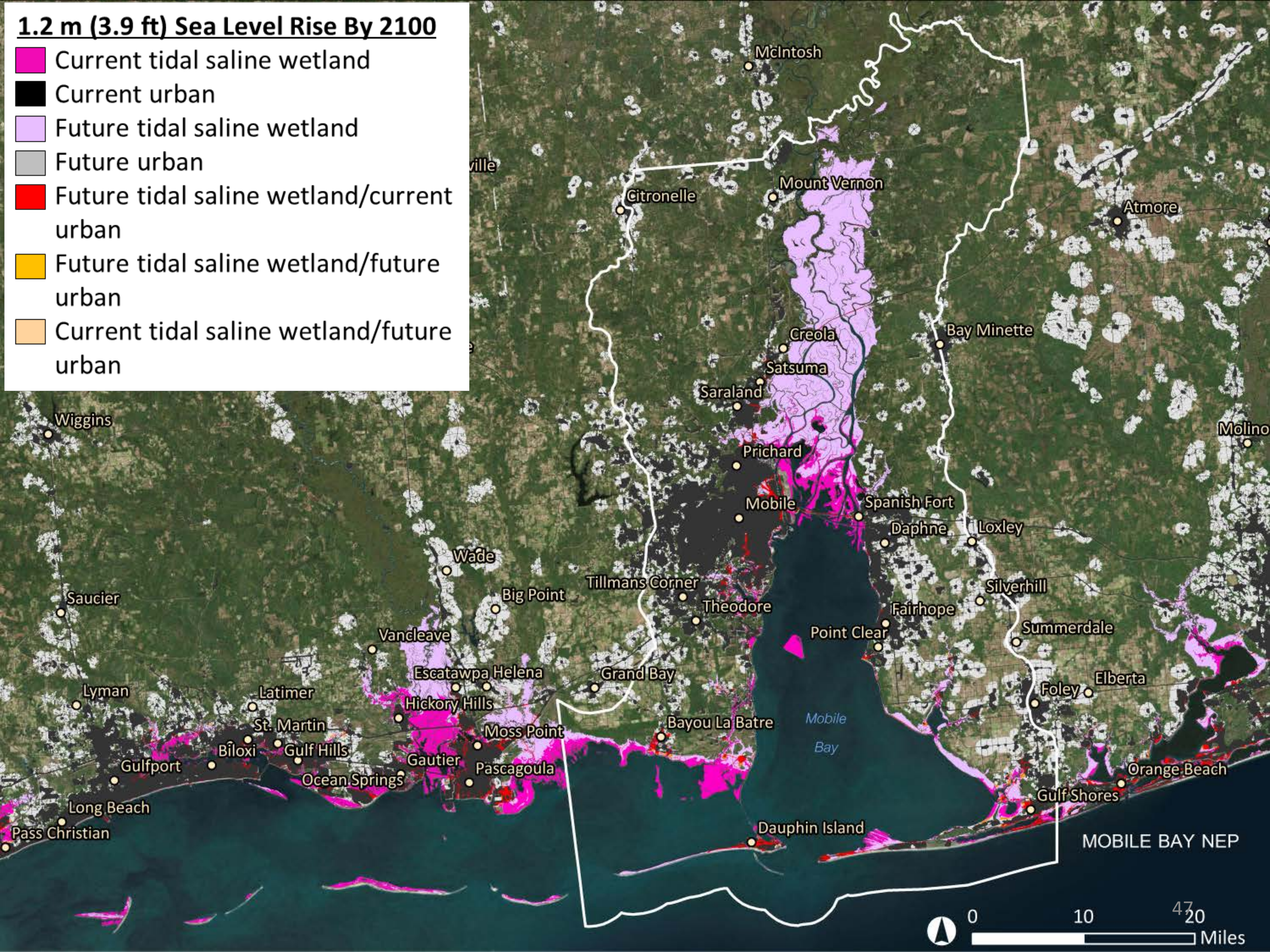
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Moss Point
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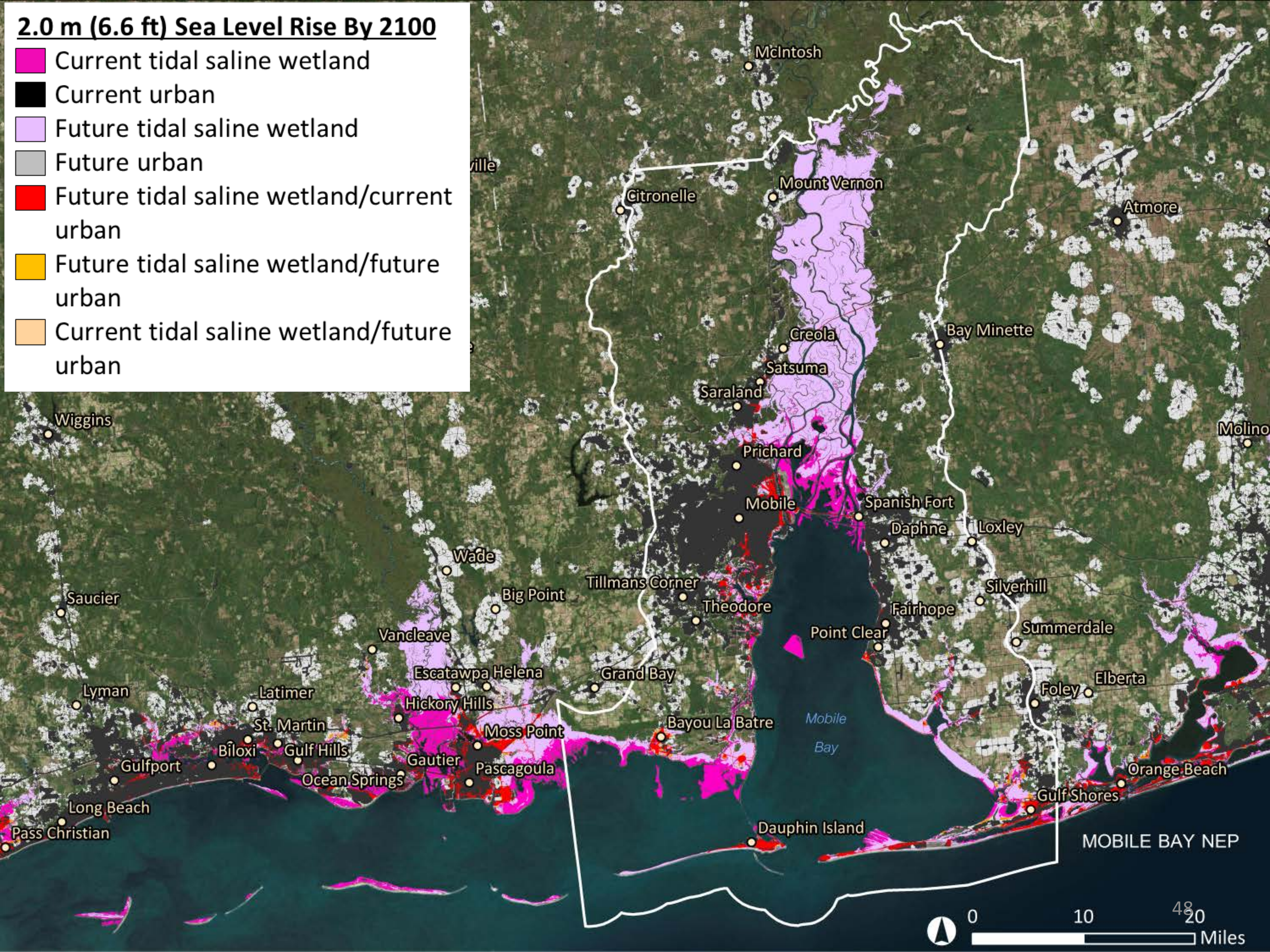
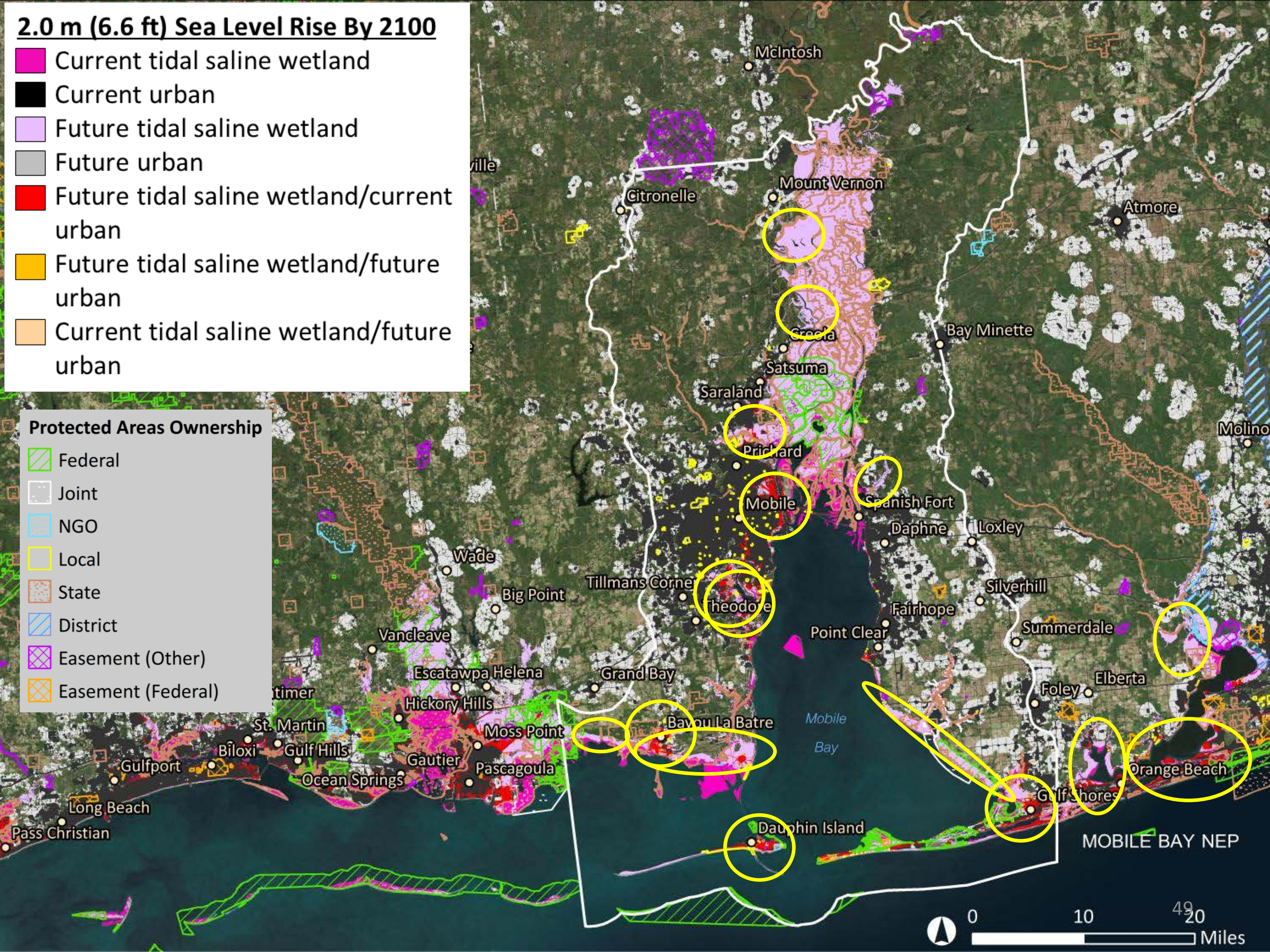

2.0 m (6.6 ft) Sea Level Rise By 2100
Current tidal saline wetland
Current urban
Future tidal saline wetland
Future urban
Future tidal saline wetland/current urban
Future tidal saline wetland/future urban
Current tidal saline wetland/future urban
McIntosh
Mount Vernon
Citronelle
Atmore
Bay Minette
Creola
Satsuma
Saraland
Wiggins
Molino
Prichard
Mobile
Spanish Fort
Daphne
Loxley
Wade
Tillmans Corner
Big Point
Theodore
Silverhill
Saucier
Fairhope
Summerdale
Vancleave
Point Clear
Escatawpa
Helena
Grand Bay
Elberta
Foley
Lyman
Latimer
Hickory Hills
St. Martin
Moss Point
Bayou La Batre
Mobile Bay
Biloxi
Gulf Hills
Gulfport
Gautier
Pascagoula
Ocean Springs
Orange Beach
Gulf Shores
Long Beach
Pass Christian
Dauphin Island
MOBILE BAY NEP
0
10
20
Miles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MOBILE BAY NEP
0
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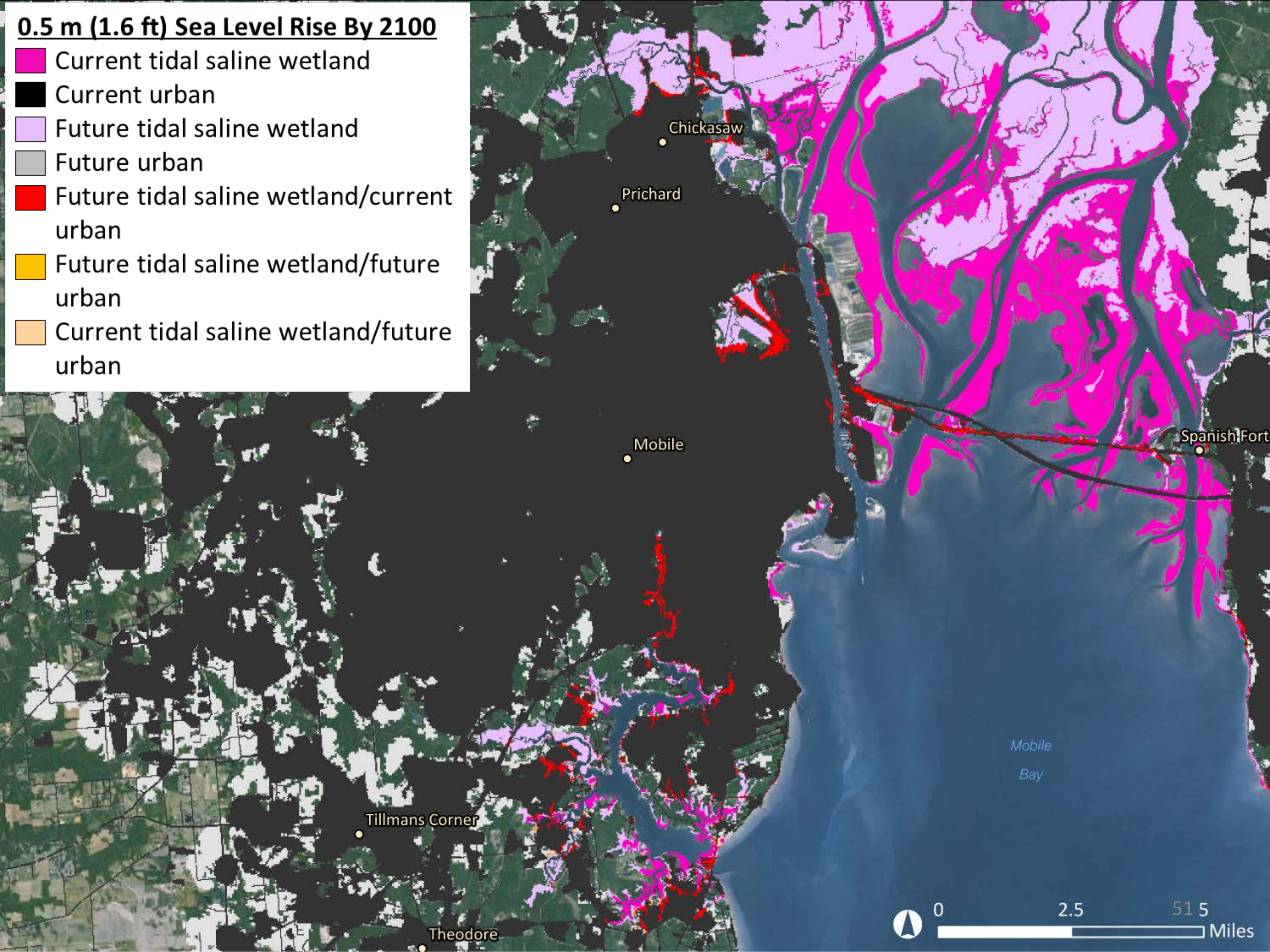
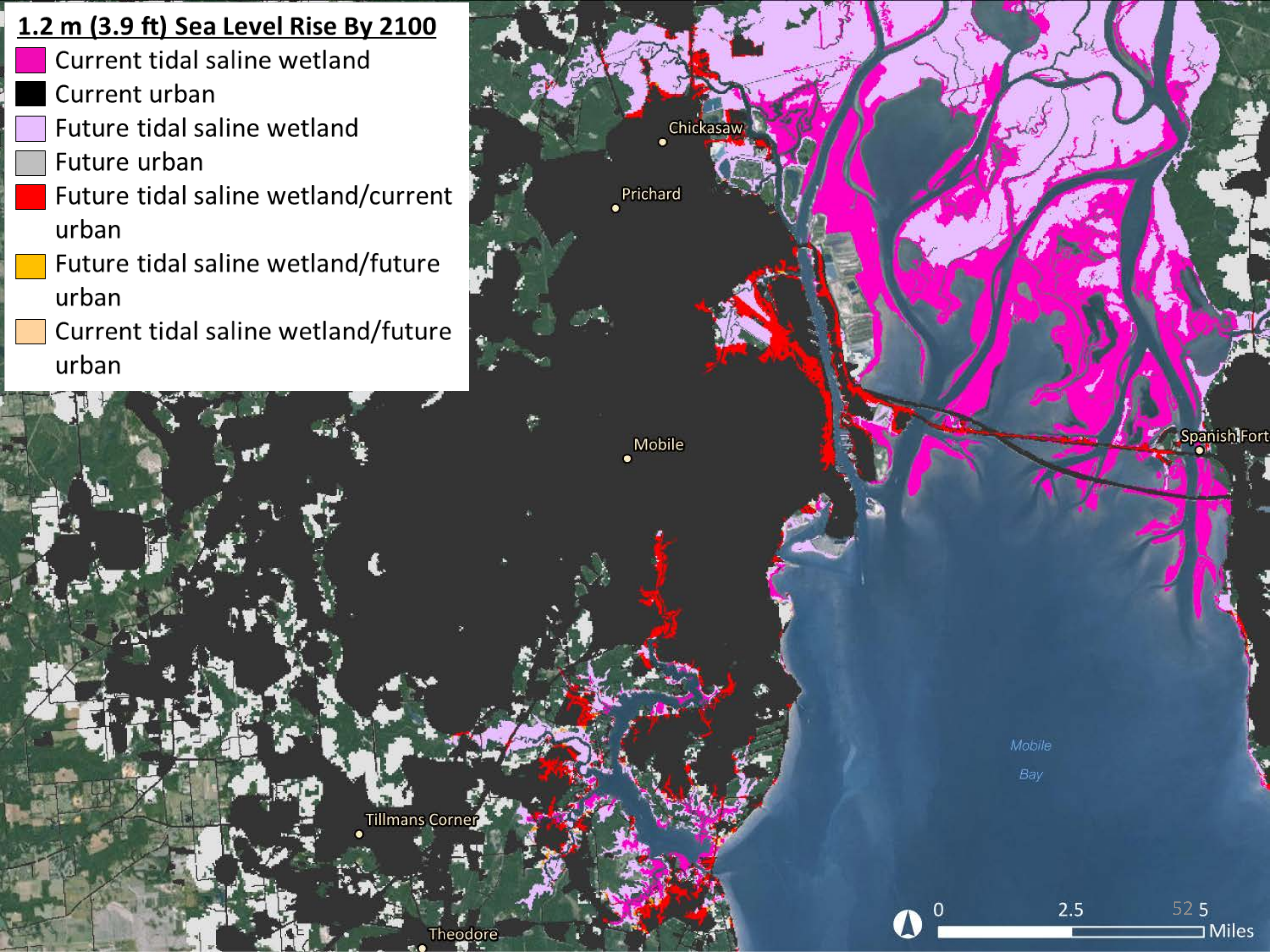
20
Miles

Mobile Area


0.5 m (1.6 ft) Sea Level Rise By 2100
Current tidal saline wetland
Current urban
Future tidal saline wetland
Future urban
Future tidal saline wetland/current urban
Future tidal saline wetland/future urban
Current tidal saline wetland/future urban
Chickasaw
Prichard
Mobile
Spanish Fort
Mobile Bay
Tillmans Corner
Theodore
0
2.5
5
Miles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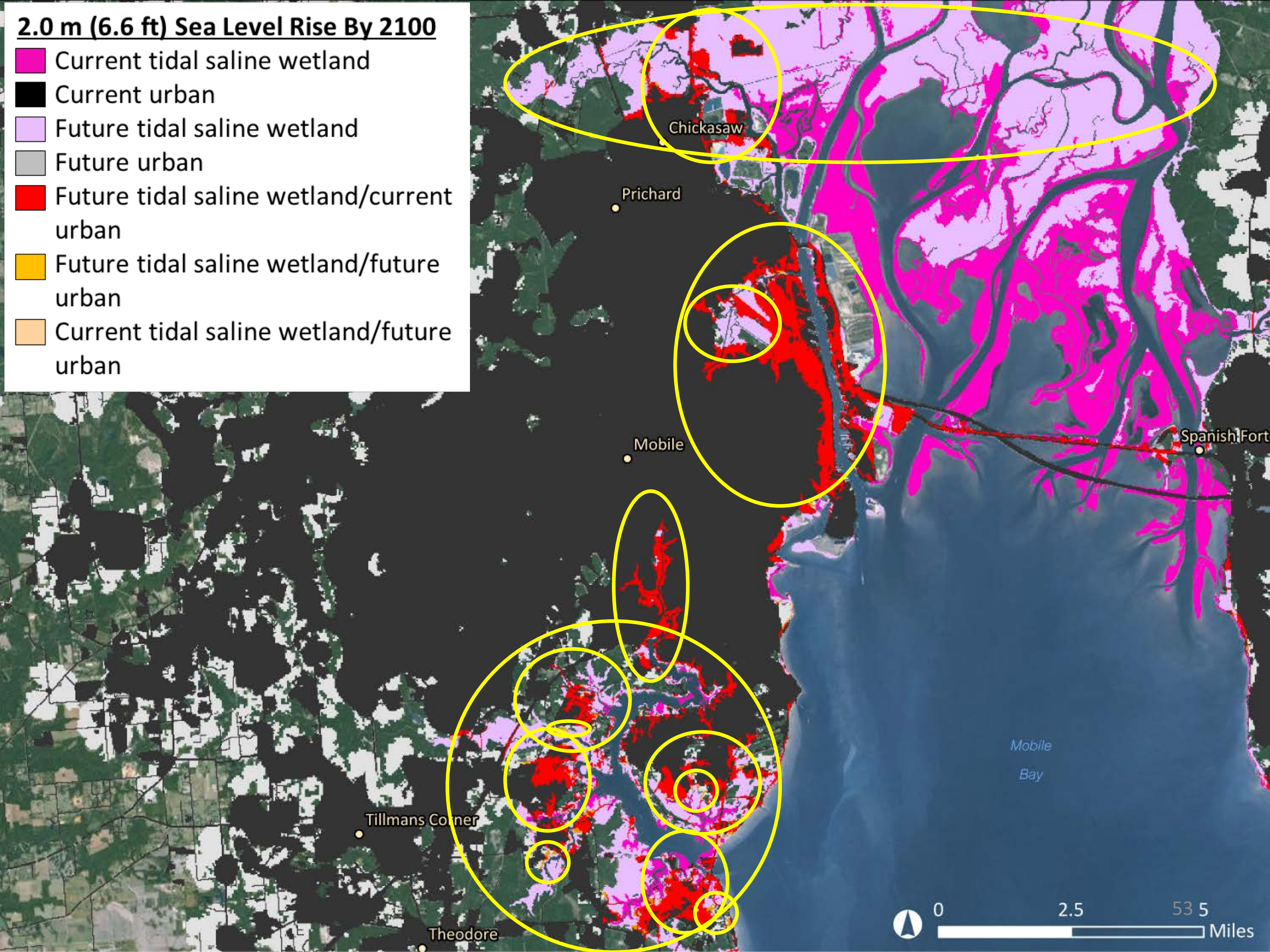
Current tidal saline wetland
Current urban
Future tidal saline wetland
Future urban
Future tidal saline wetland/current urban
Future tidal saline wetland/future urban
Current tidal saline wetland/future urban
Chickasaw
Prichard
Mobile
Spanish Fort
Mobile Bay
Tillmans Corner
Theodore
0
2.5
5
Miles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Current tidal saline wetland/future urban
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Prichard
Mobile
Spanish Fort
Tillmans Corner
Theodore
Mobile Bay
0
2.5
5
Miles
53

Local Work: Perch Creek (Dog River Tributary)

- Habitat assessments of areas of interest for conservation
- Deter development of upland buffers in these AOIs to facilitate salt marsh migration, filter pollutants, and mitigate flooding

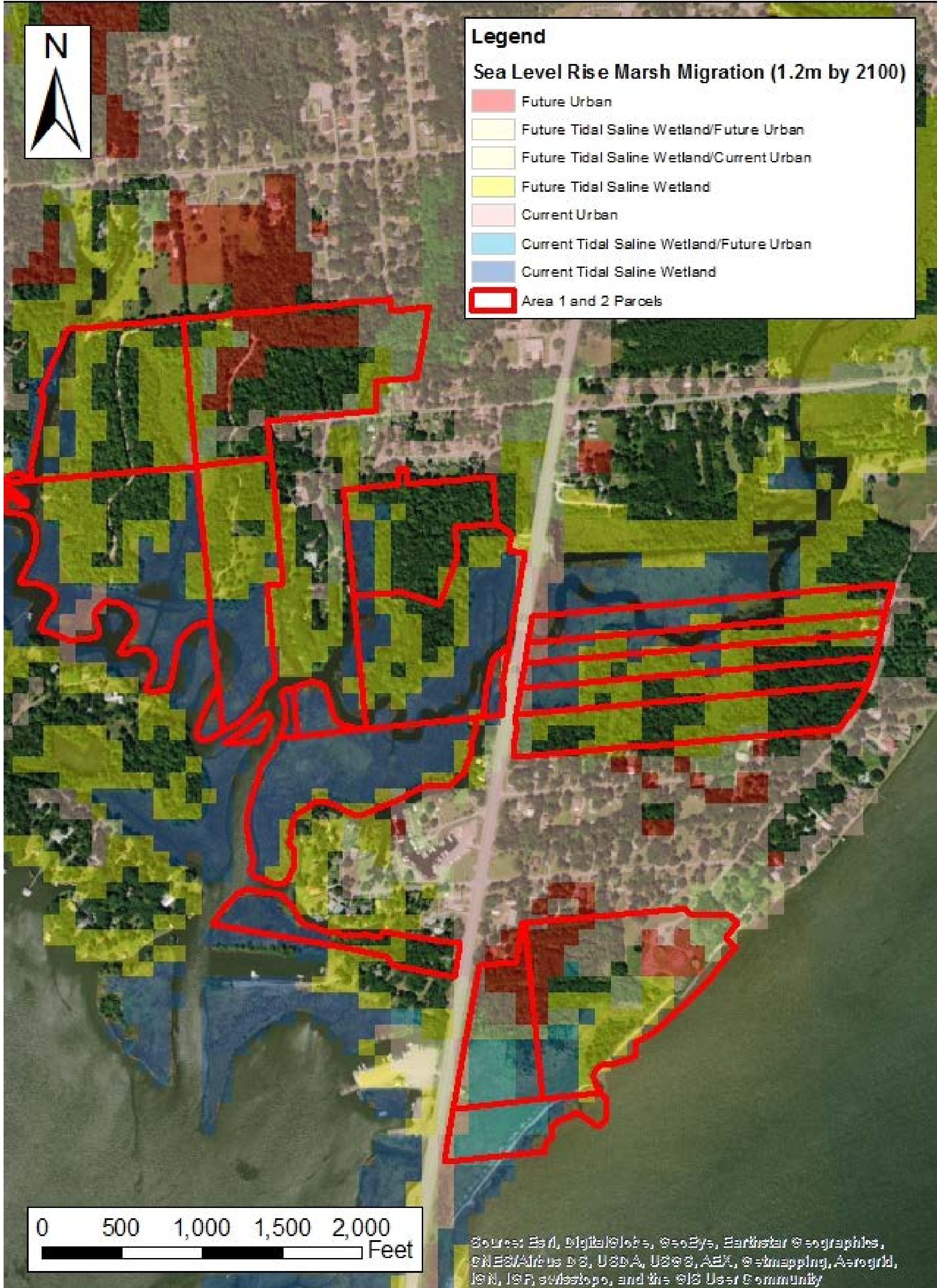
Source: City of Mobile and Moffatt & Nichol

USGS

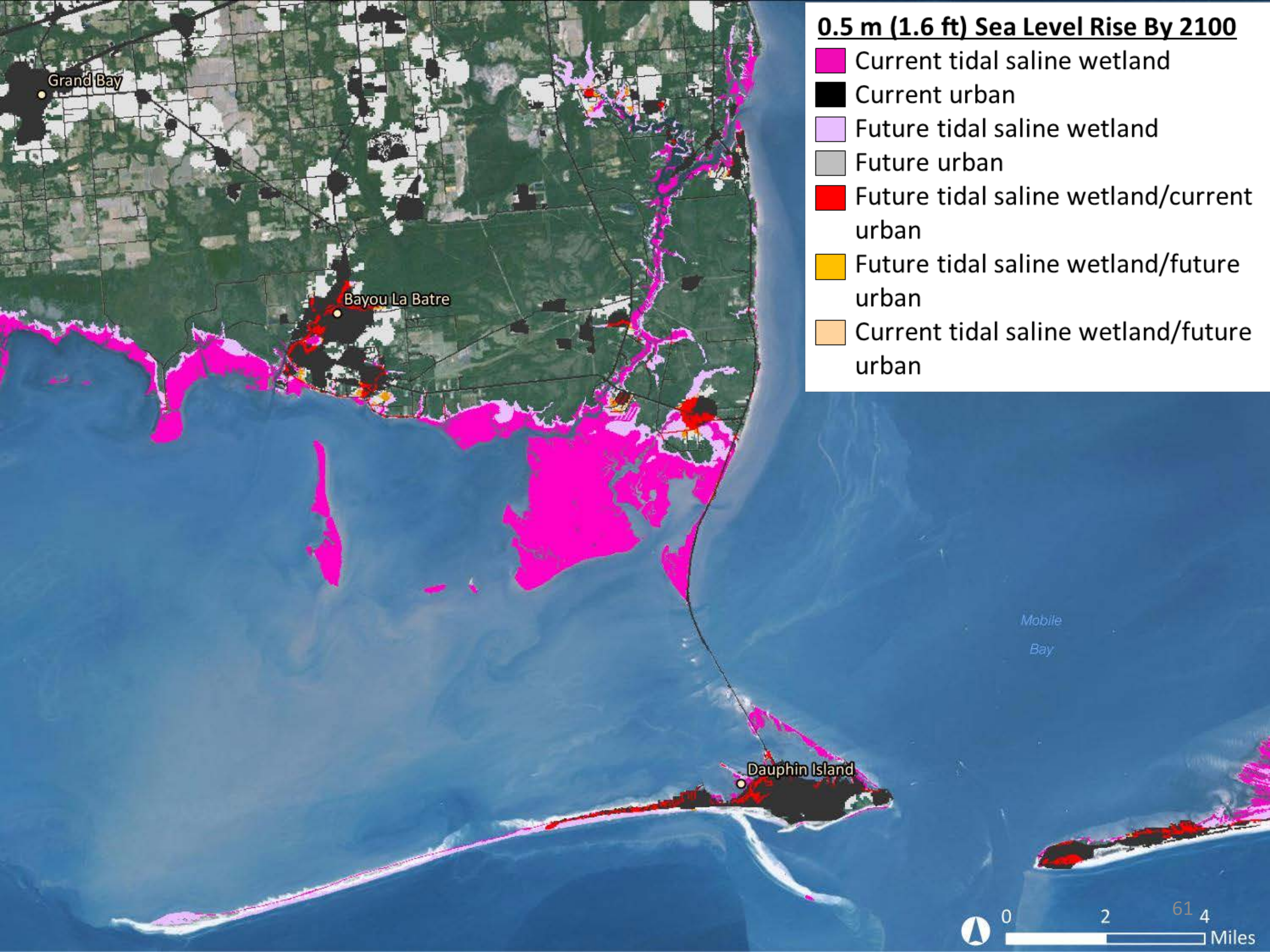
- Under intermediate high SLR scenario
  – 63 acres to TSW (33% of Area 1)
  – 5.5 acres protected from urbanization

- Unique – fewer barriers to migration

Source: City of Mobile and Moffatt & Nichol



Dauphin Island and Bayou La Batre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Current tidal saline wetland/future urban
Grand Bay
Bayou La Batre
Dauphin Island
Mobile Bay
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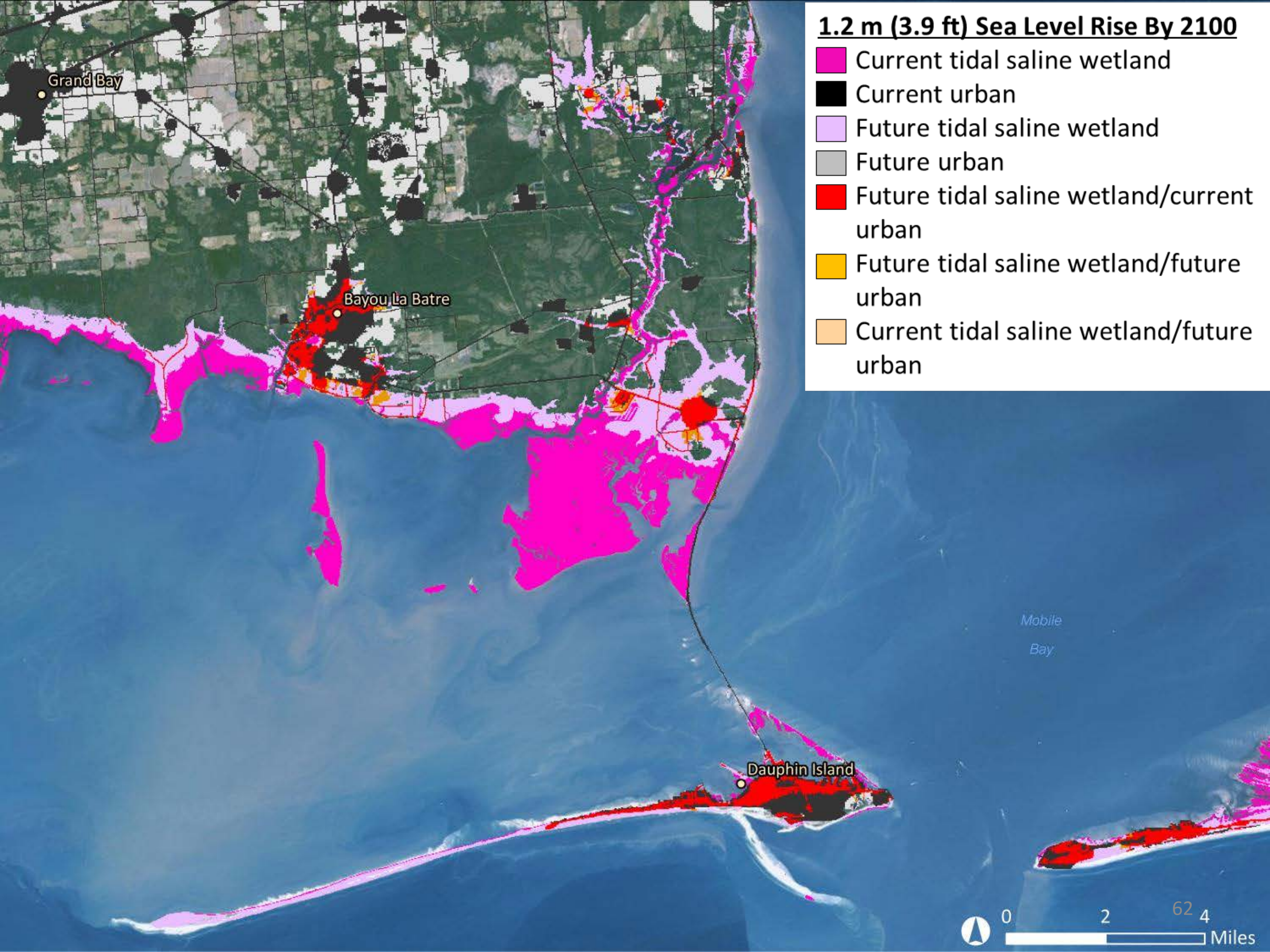
Miles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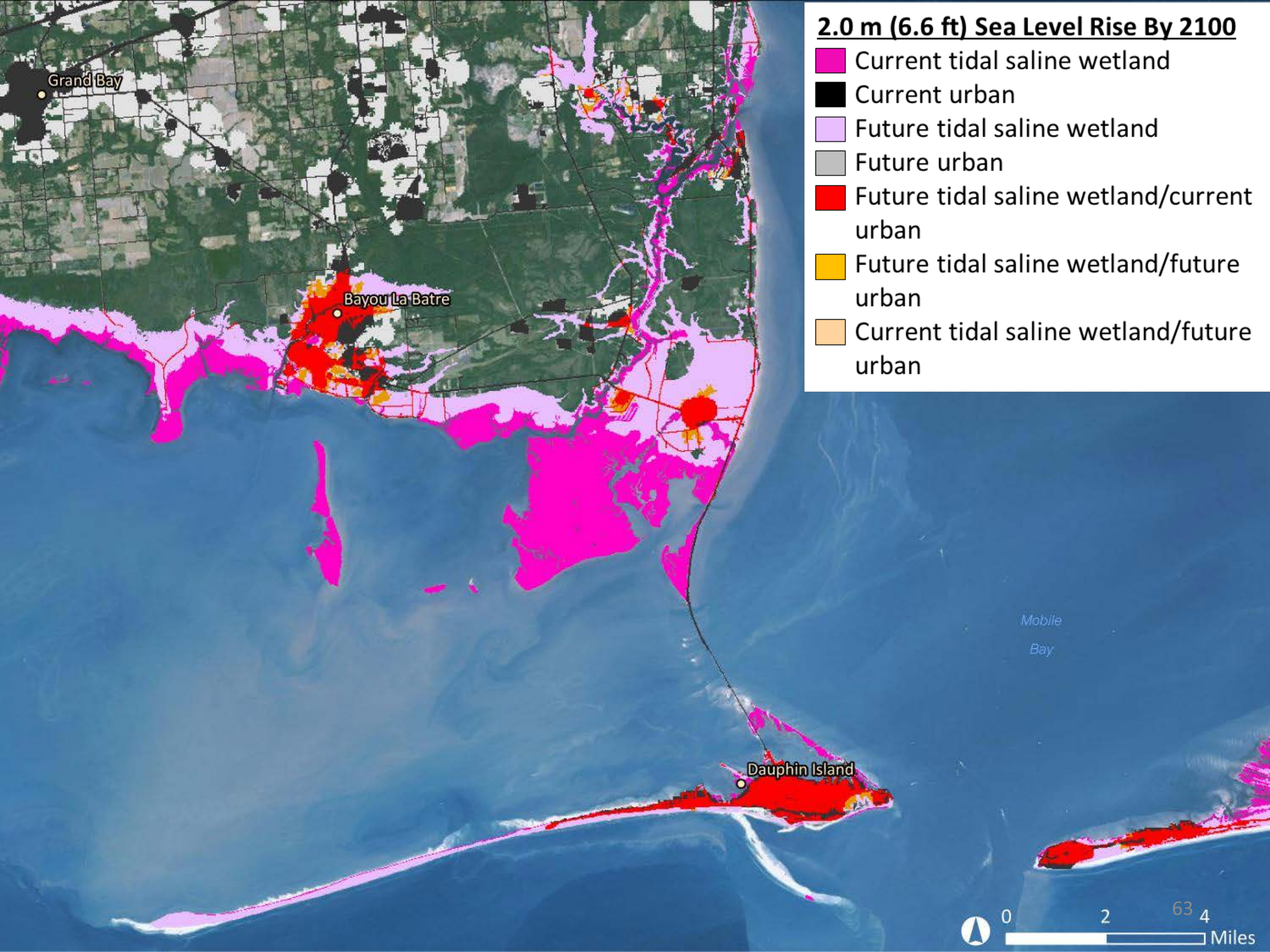
Miles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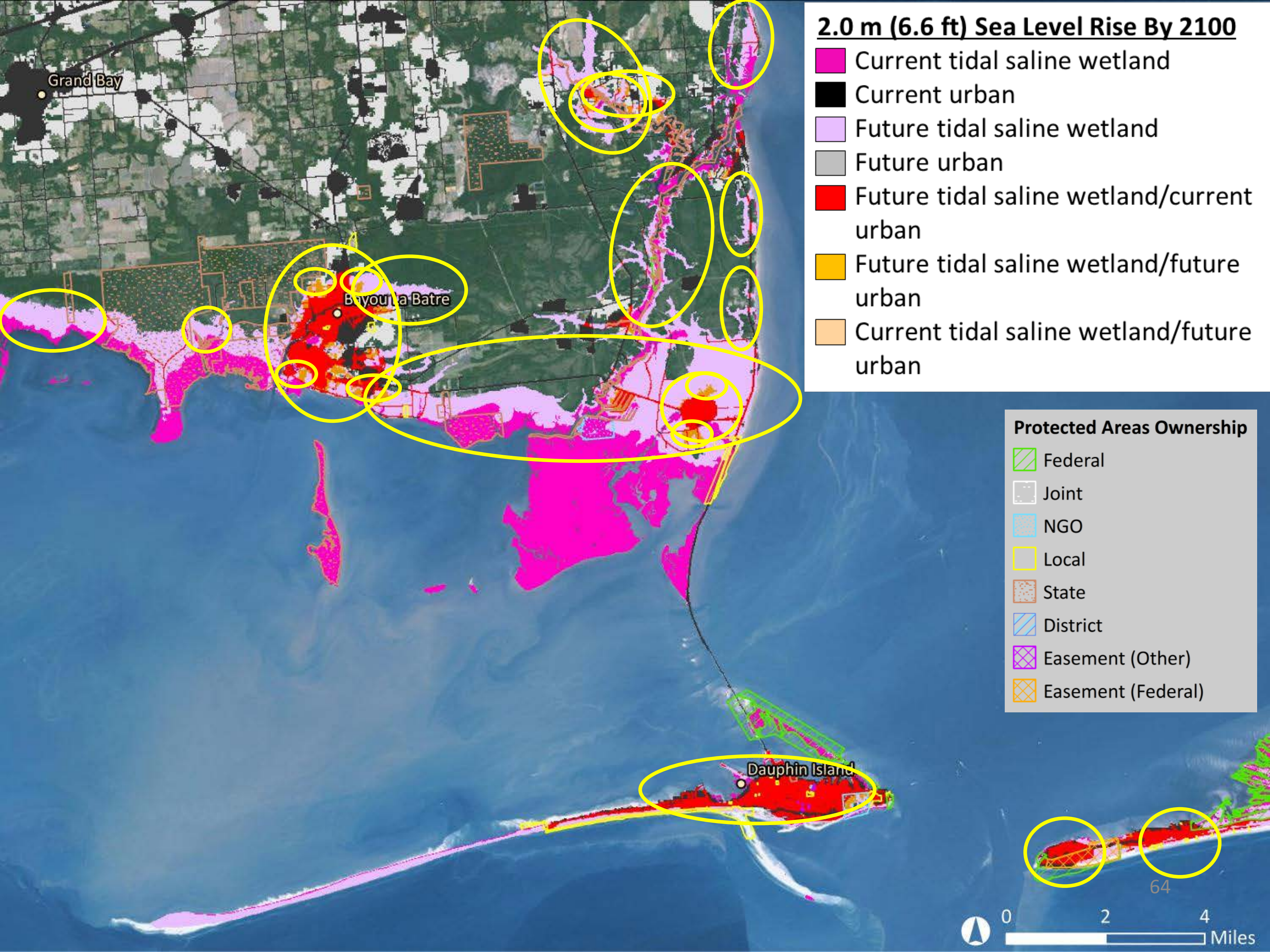

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Dauphin Island
0
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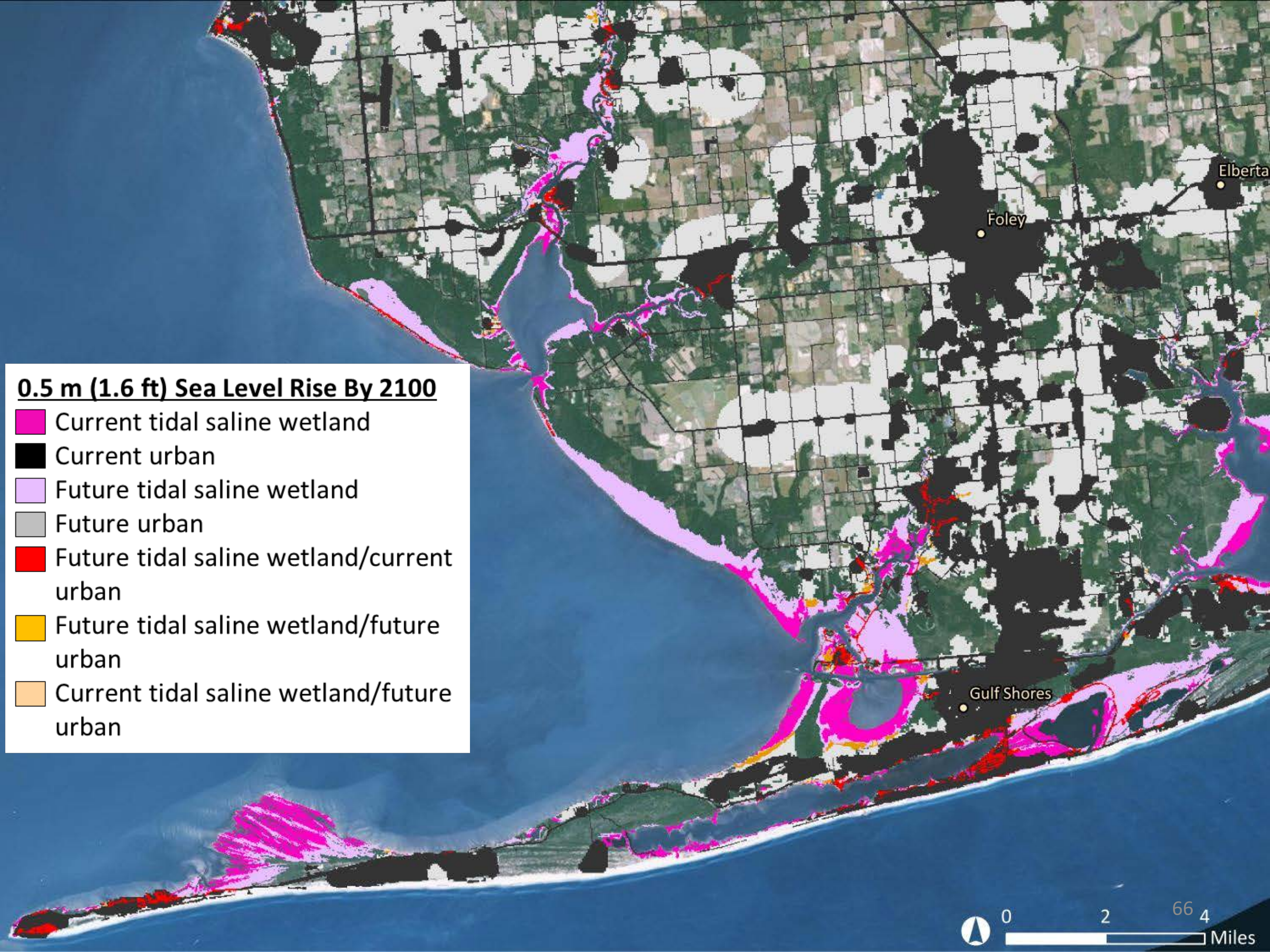
Miles

Gulf Shores and Bon Secour NWR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Foley
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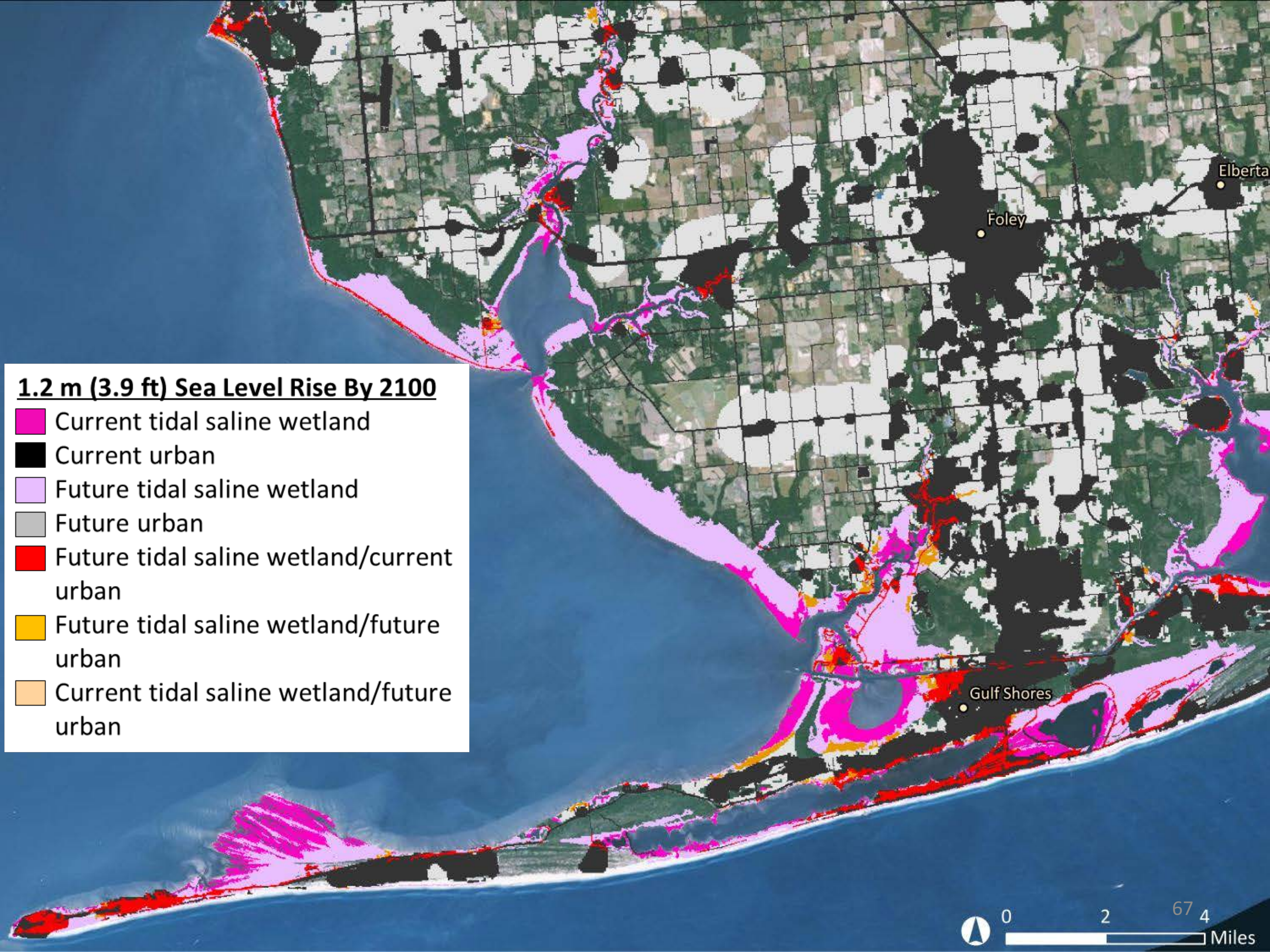
Miles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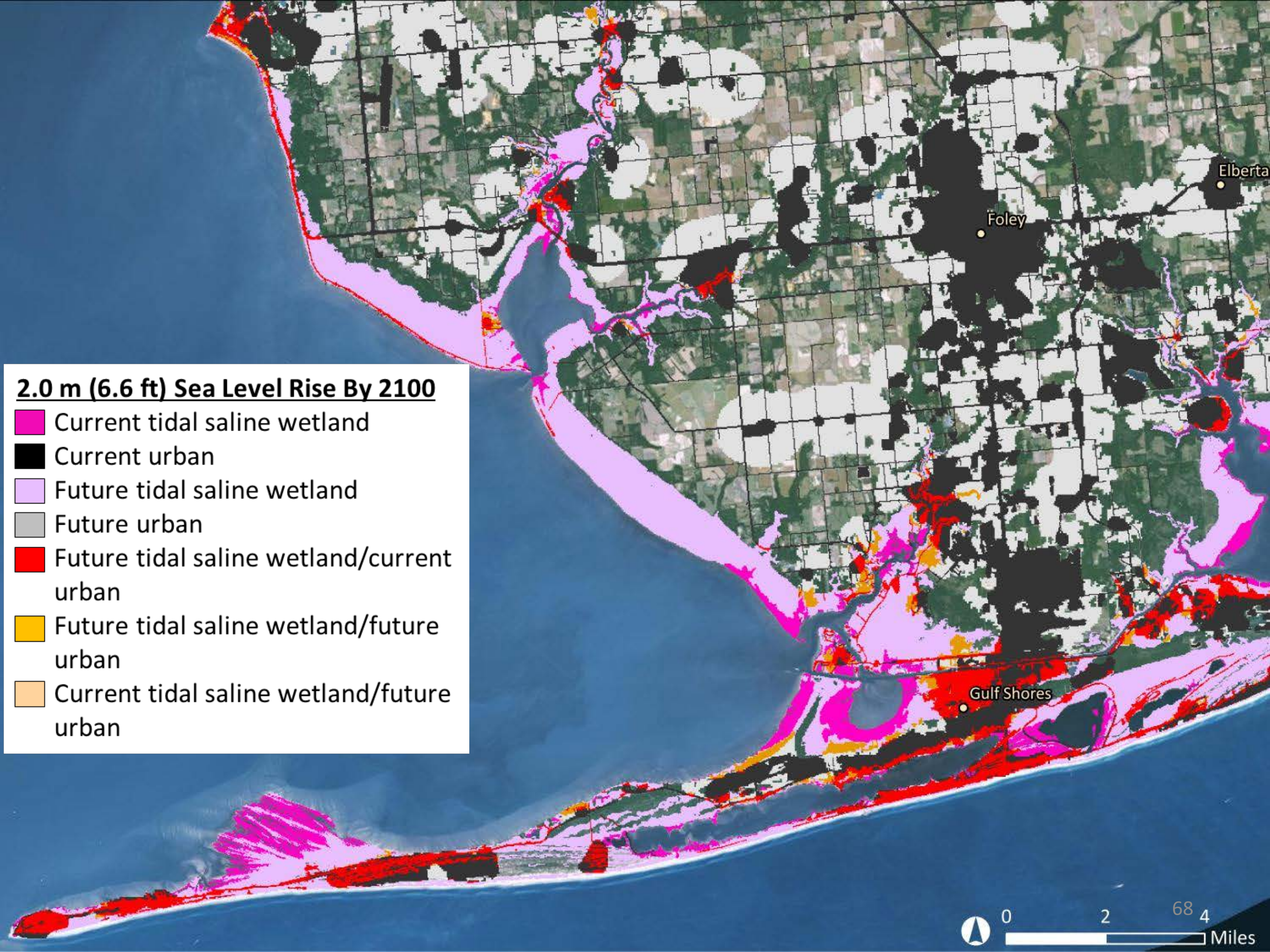
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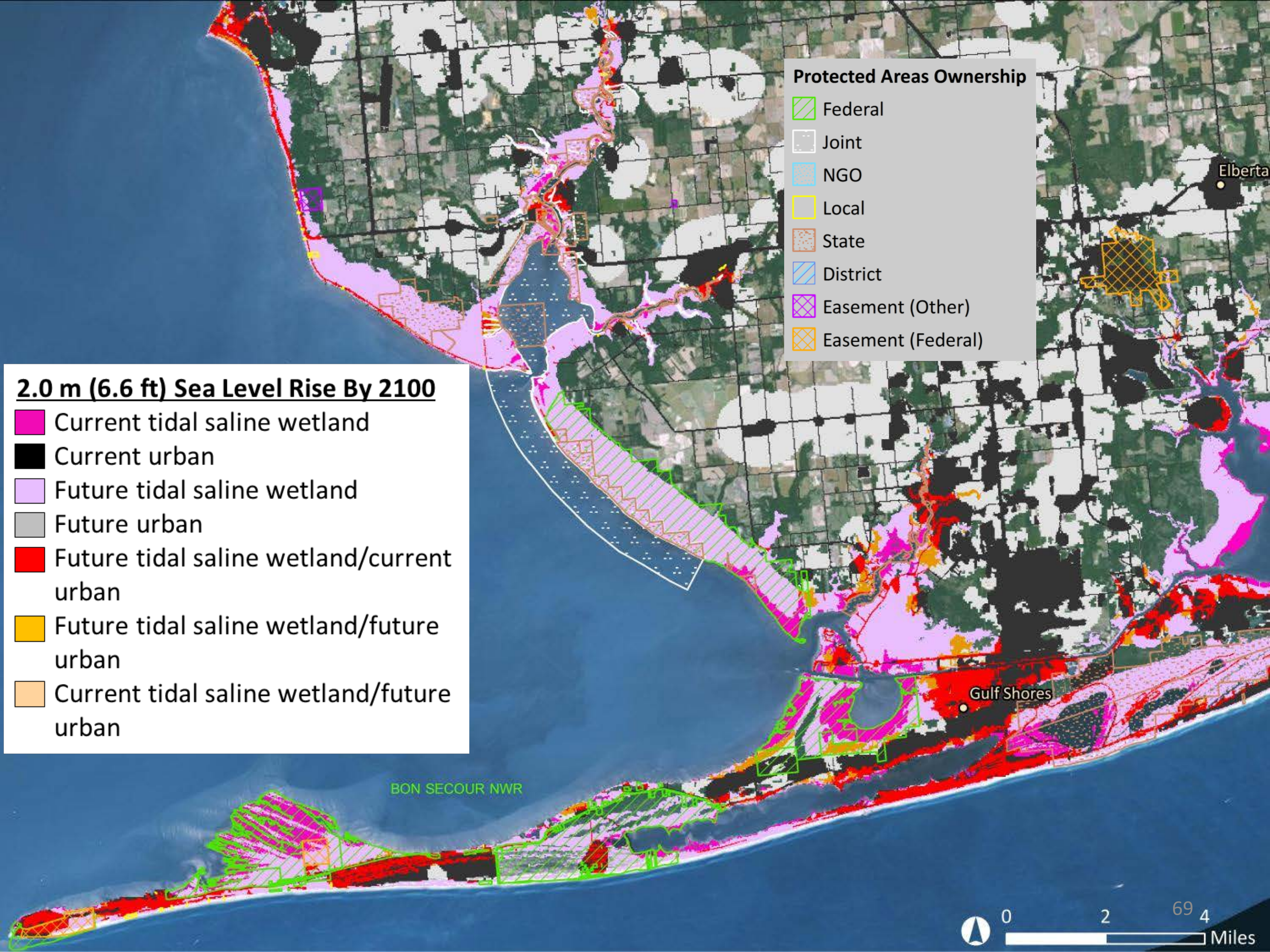
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BON SECOUR NWR
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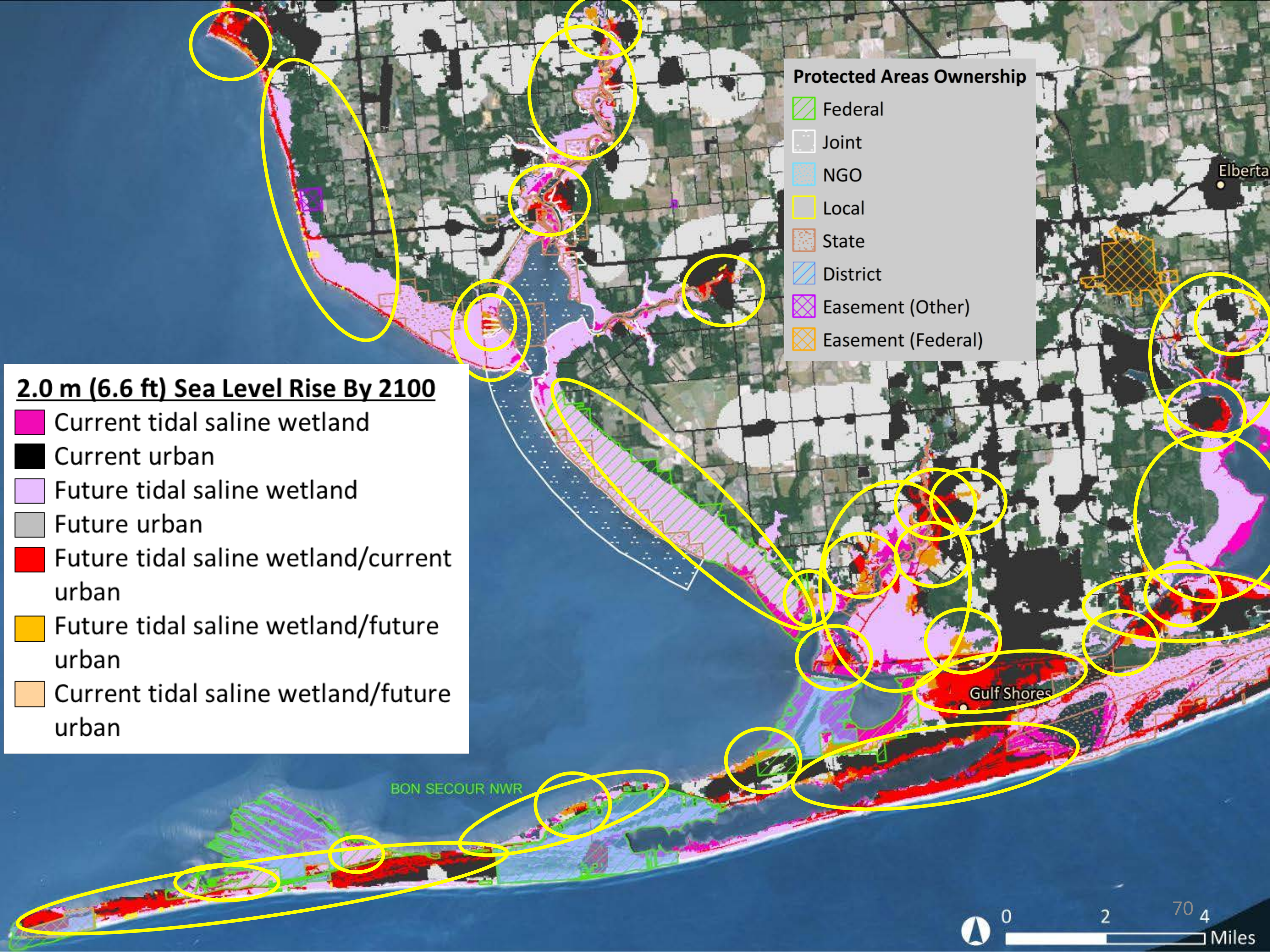

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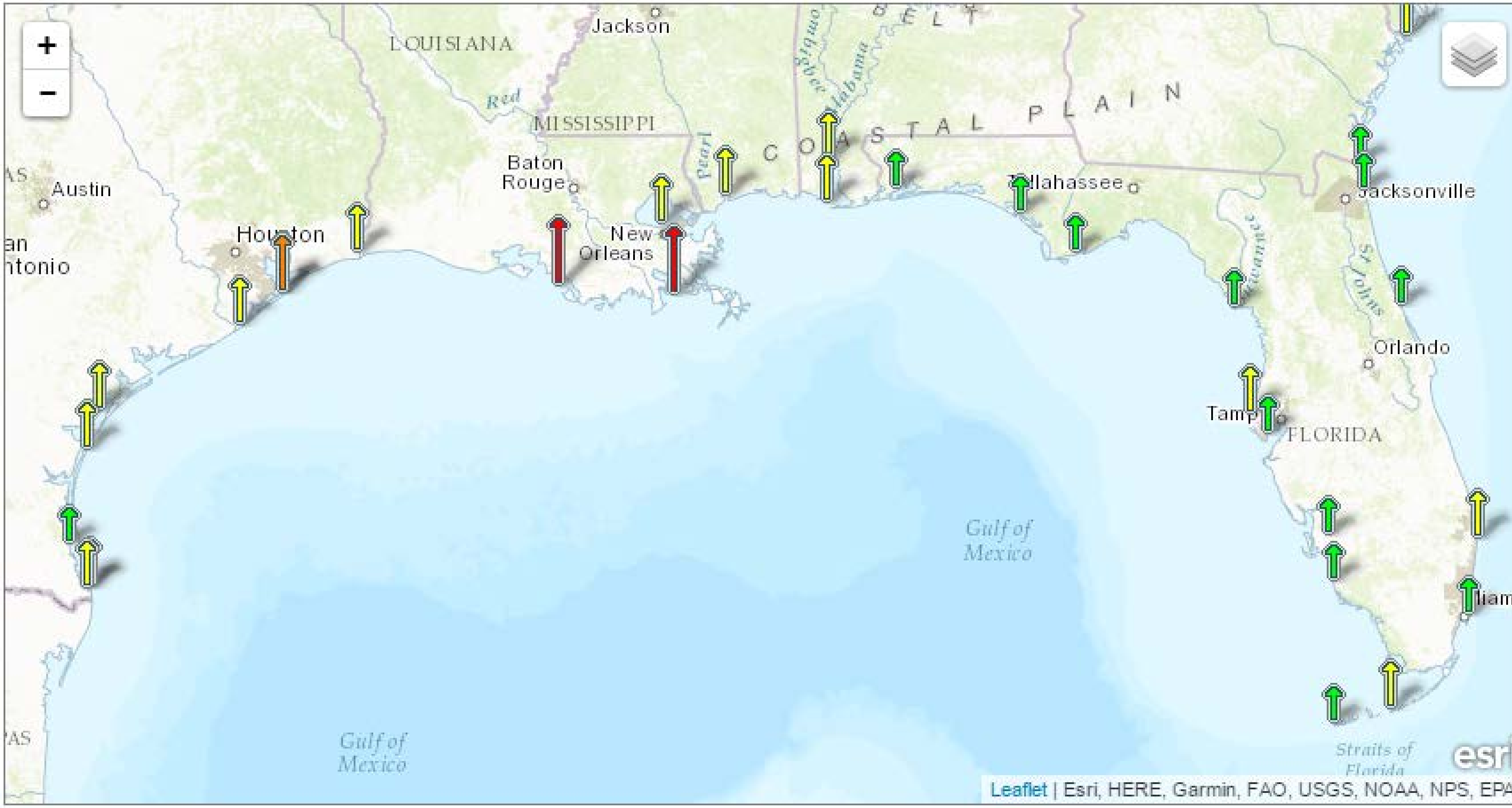
2
4
Miles

Questions?

SLEUTH Output (Terando et al. 2014)

- SLEUTH simulates four types of urban growth patterns:
  1. Spontaneous growth
  2. New spreading urban centers
  3. Edge growth around existing urban areas
  4. Road-influenced growth
- Inputs:
  1. A layer of areas excluded from development or highly resistant to urbanization (e.g., water bodies, wetlands)
  2. Topographic layers (ease of developing an area)
  3. The transportation network for at least three time periods
  4. The historic urban extent for at least time periods

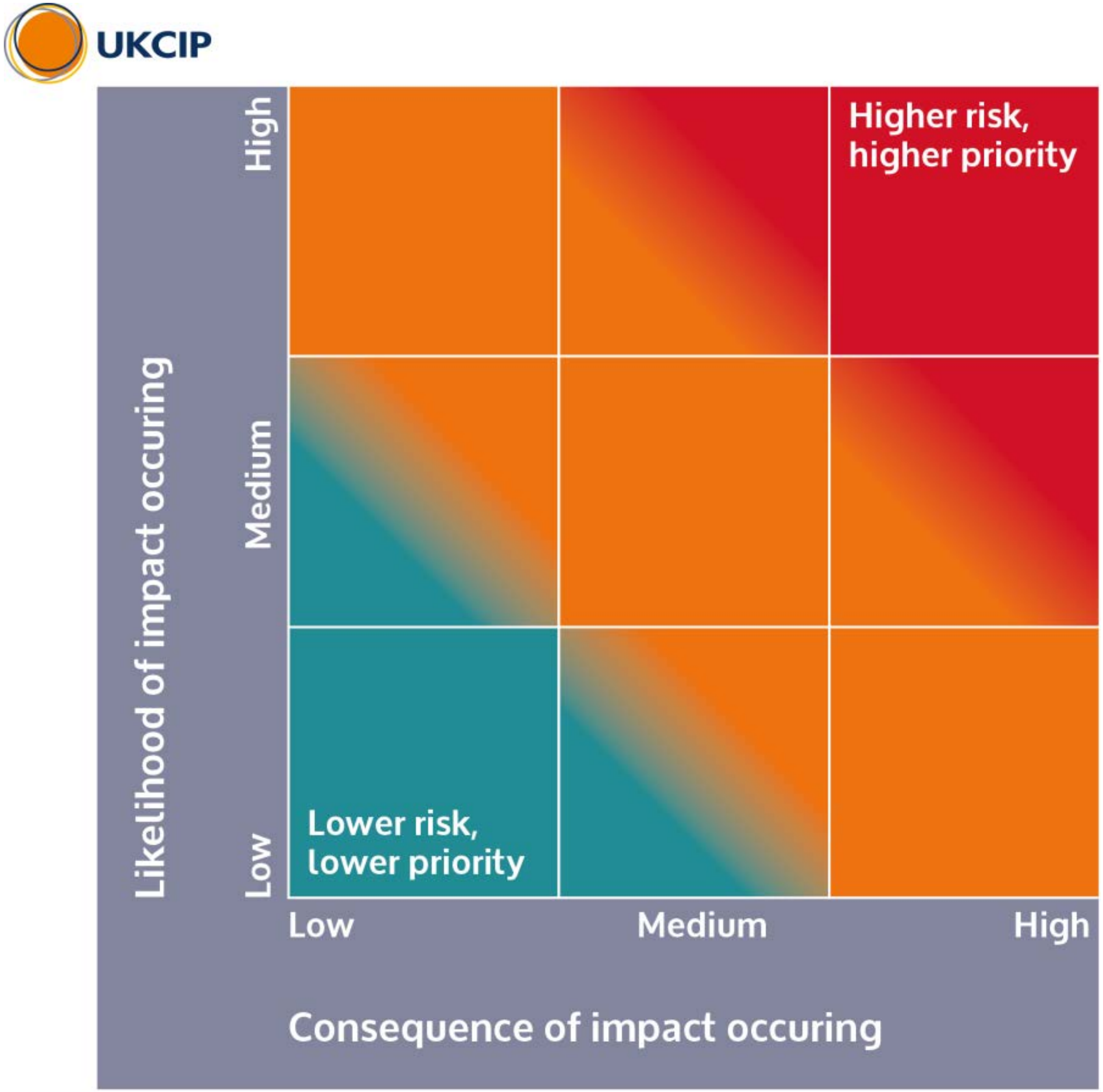


Sea Level Trends
mm/yr (feet/century)

15 to 21 (5 to 7)	6 to 9 (2 to 3)	-3 to 0 (-1 to 0)	-12 to -9 (-4 to -3)
12 to 15 (4 to 5)	3 to 6 (1 to 2)	-6 to -3 (-2 to -1)	-15 to -12 (-5 to -4)
9 to 12 (3 to 4)	0 to 3 (0 to 1)	-9 to -6 (-3 to -2)	-18 to -15 (-6 to -5)

Averaged by month – local relative mean sea level trends

Source: https://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml



Source: http://www.ukcip.org.uk/wizard/future-climate-vulnerability/

Calculating regional SLR

Equation: $y = a(t_1 - t_0) + b(t_1 - t_0)^2$

Where:

y = SLR in m/year or mm/year

a = rate of historical SLR in mm/year

t_0 = start time step

t_1 = end time step

b = acceleration constant

Scenarios and time steps

Variables	Values
Scenarios	0.5, 1.0, 1.2, 1.5, and 2.0
Time steps	Current, 2030, 2040, 2050, 2060, and 2100
Rate of Historical SLR (a)	1.7 mm/year*
Start time step (t_0)	1992~

* Church and White 2011, IPCC 2013

~ Middle of Tidal Datum Epoch

SLR scenarios

y(m)	a	t_0	t_1	b
0.5	1.7	1992	2100	0.027
1	1.7	1992	2100	0.070
1.2	1.7	1992	2100	0.087
1.5	1.7	1992	2100	0.113
2	1.7	1992	2100	0.156

y = SLR in m/year or mm/year

a = rate of historical SLR in mm/year

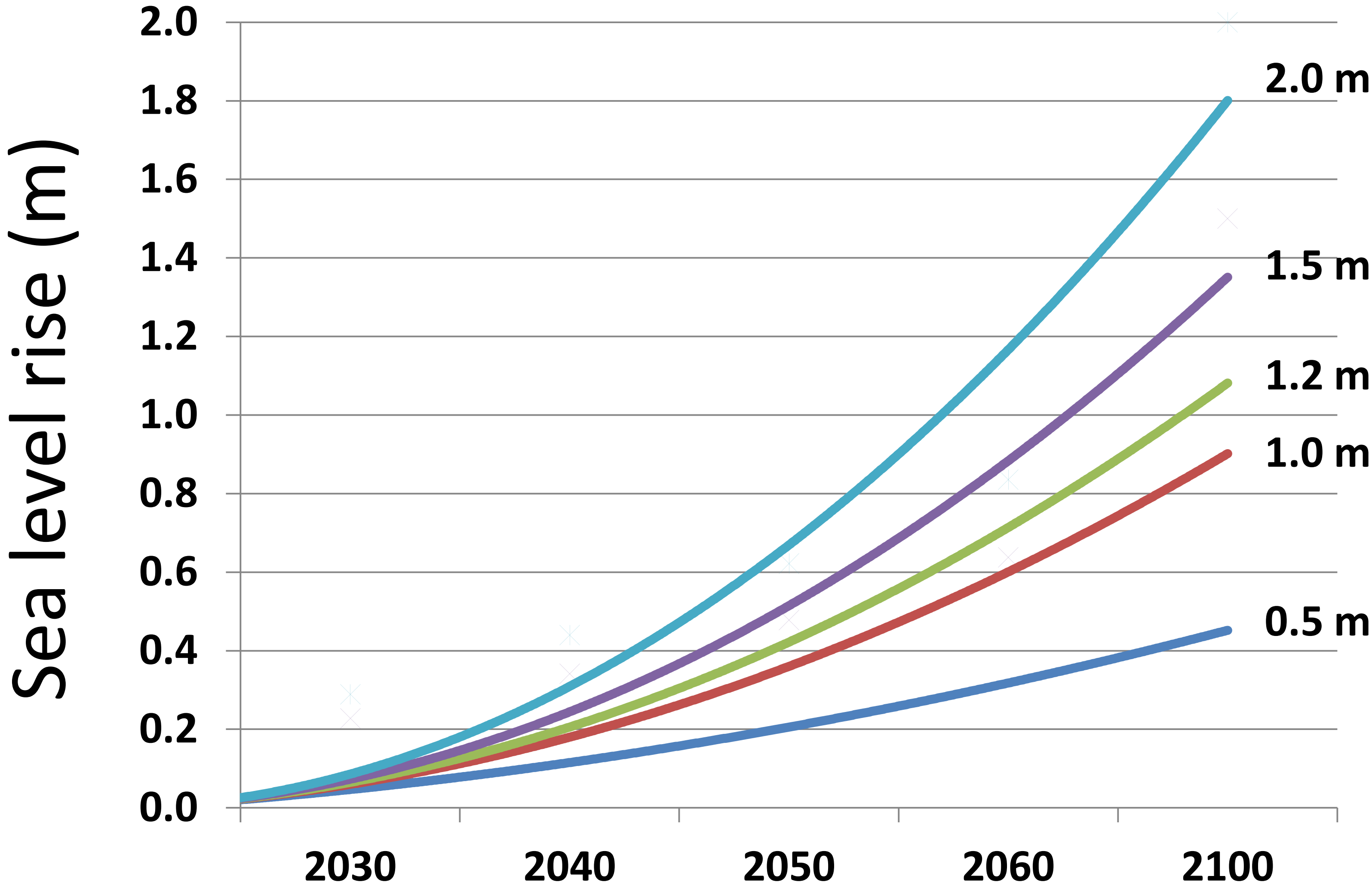
t_0 = start time step

t_1 = end time step

b = acceleration constant

Acceleration based on rate of change from 1992 to predicted 2100 scenarios

Scenarios and Time Step Combinations



SLAMM and TSW Migration

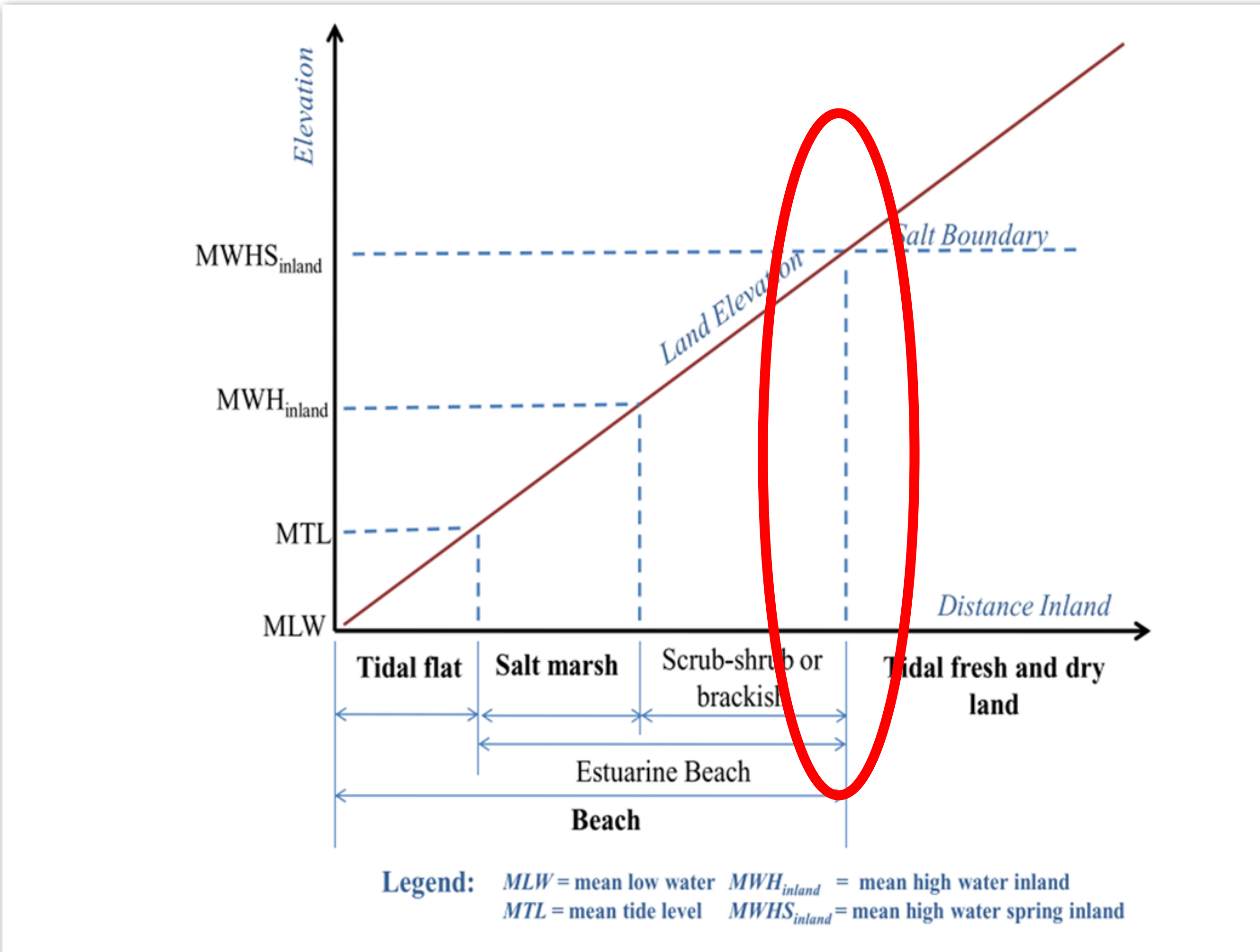
Differences Between Models

- Our focus was on the landward migration of wetlands
- Identified barriers to migration: current and future urban developments and leveed areas that overlap with migration corridors
- Gulf-wide extent vs. gold-standard modeling of smaller areas
- No attempt to predict whether current wetlands will be lost or keep pace with SLR or conversion to specific wetland types
  - Precipitation
  - Temperature
- Different method to determine wetland/upland boundary

Other groups are using tidal data to quantify the TSW boundary

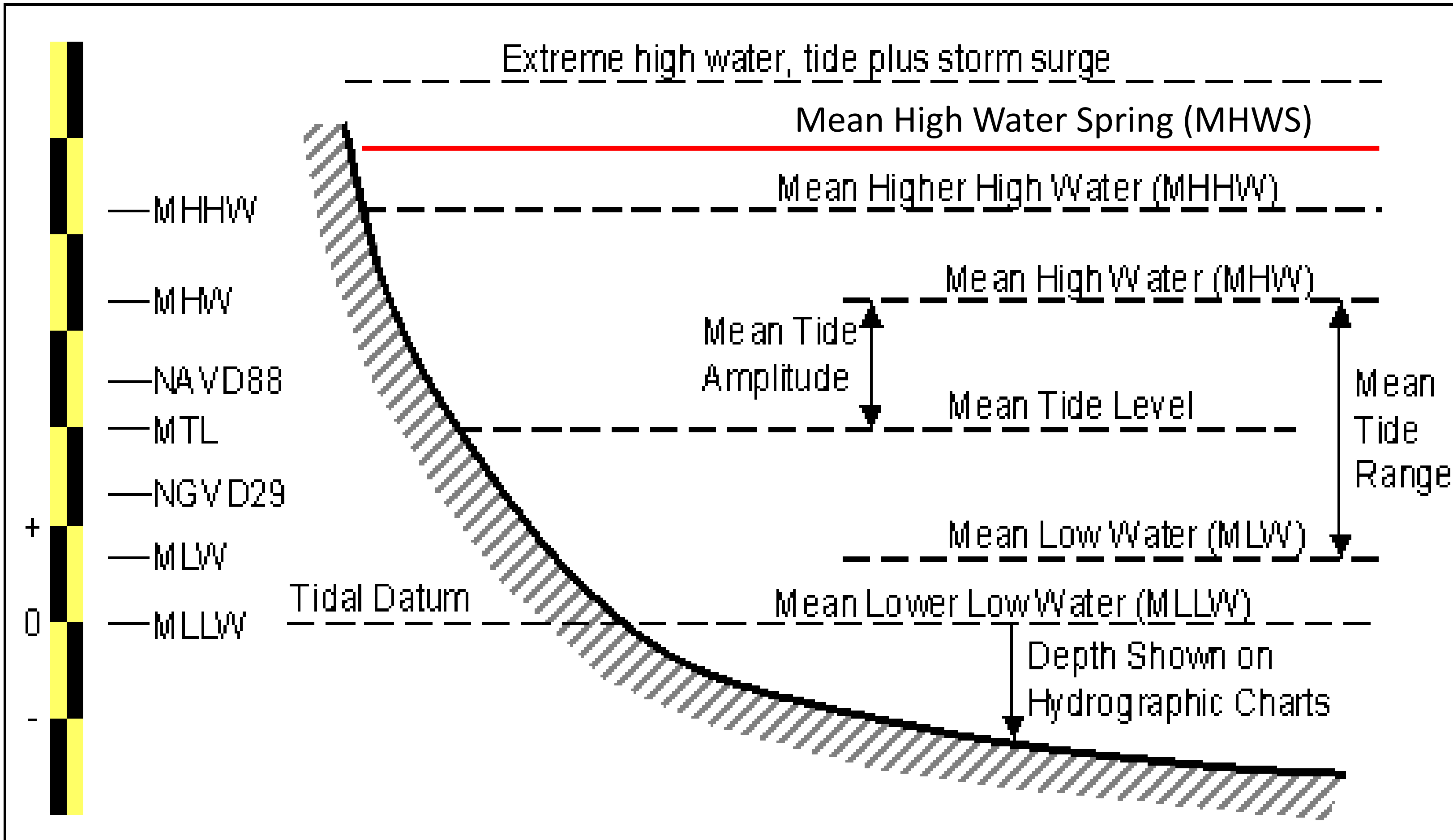
Data	Criteria	Model	Reference
Tidal	Highest elevation that is expected to flood at least once per month	SLAMM 6	Glick et al. 2013, Geselbracht et al. 2011, and more
Tidal	Modified form of the MHHW surface shifted upwards in relation to the highest tide levels in the spring	NOAA SLR Viewer	Marcy et al. 2011

Mean high water spring as a proxy



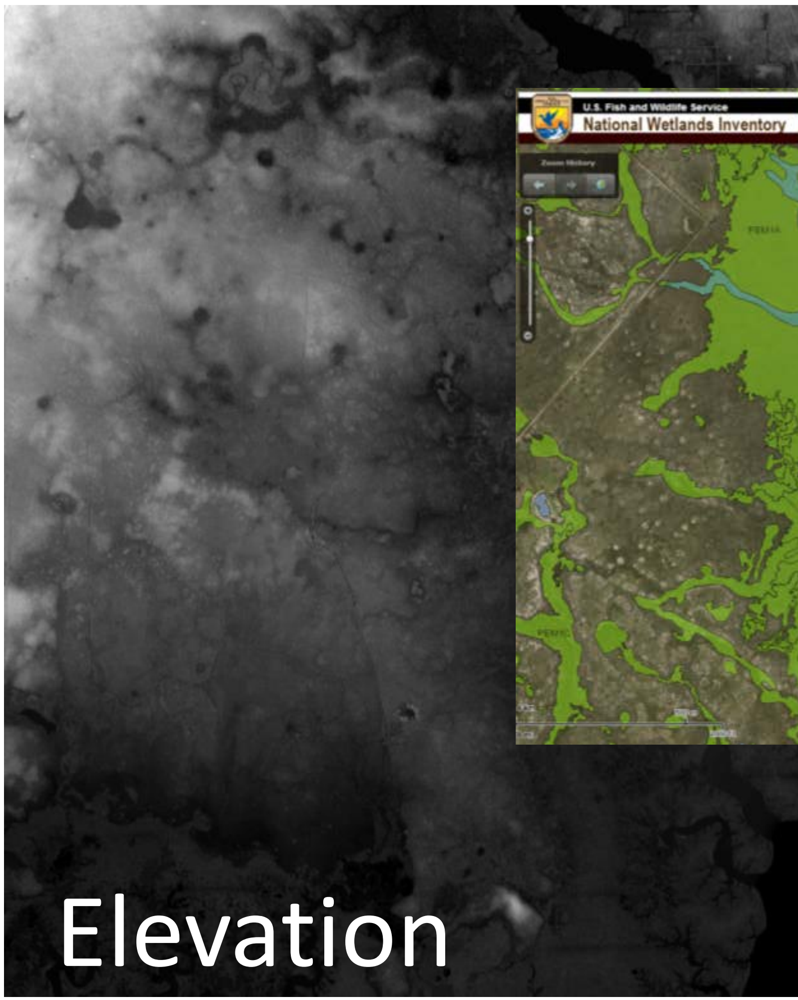
Source: Chu-Agor et al. 2011

Tidal datums: a refresher

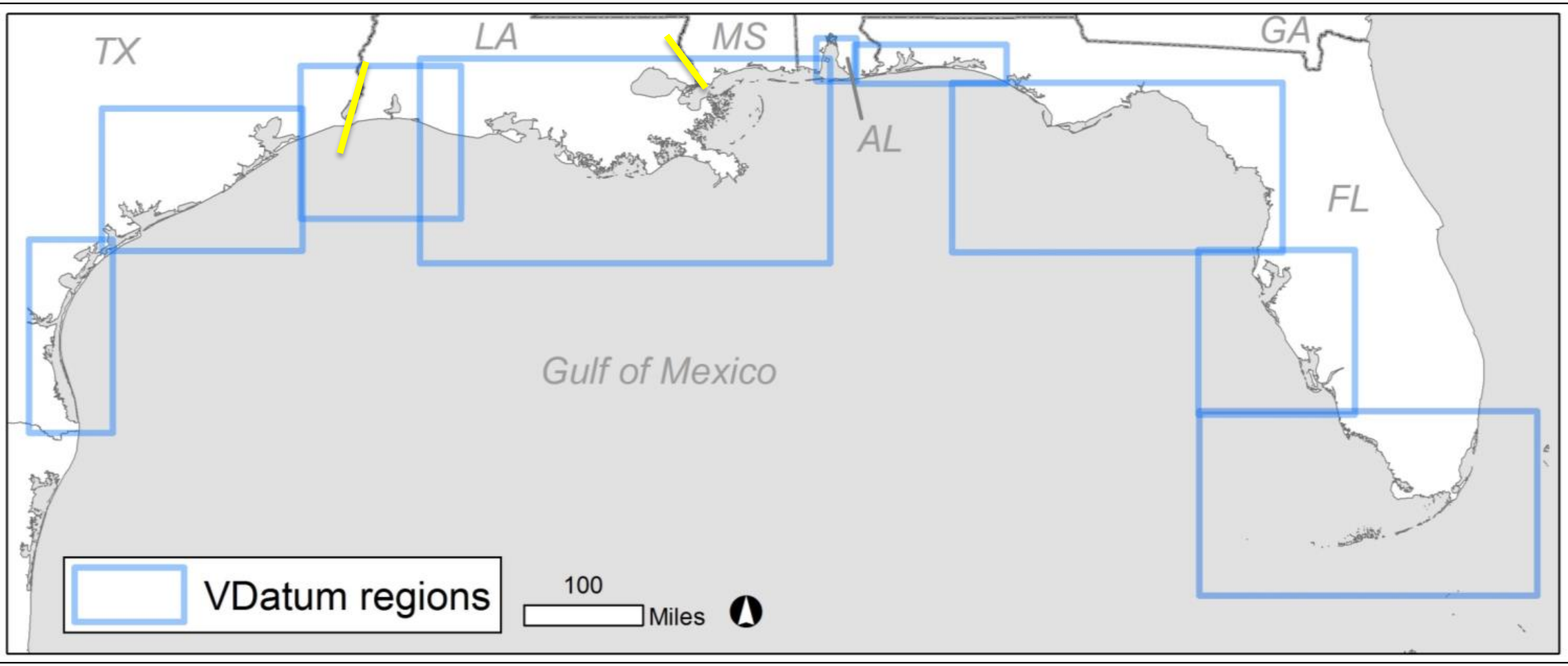


NAVD88 is a based on a geopotential surface that represents mean sea level

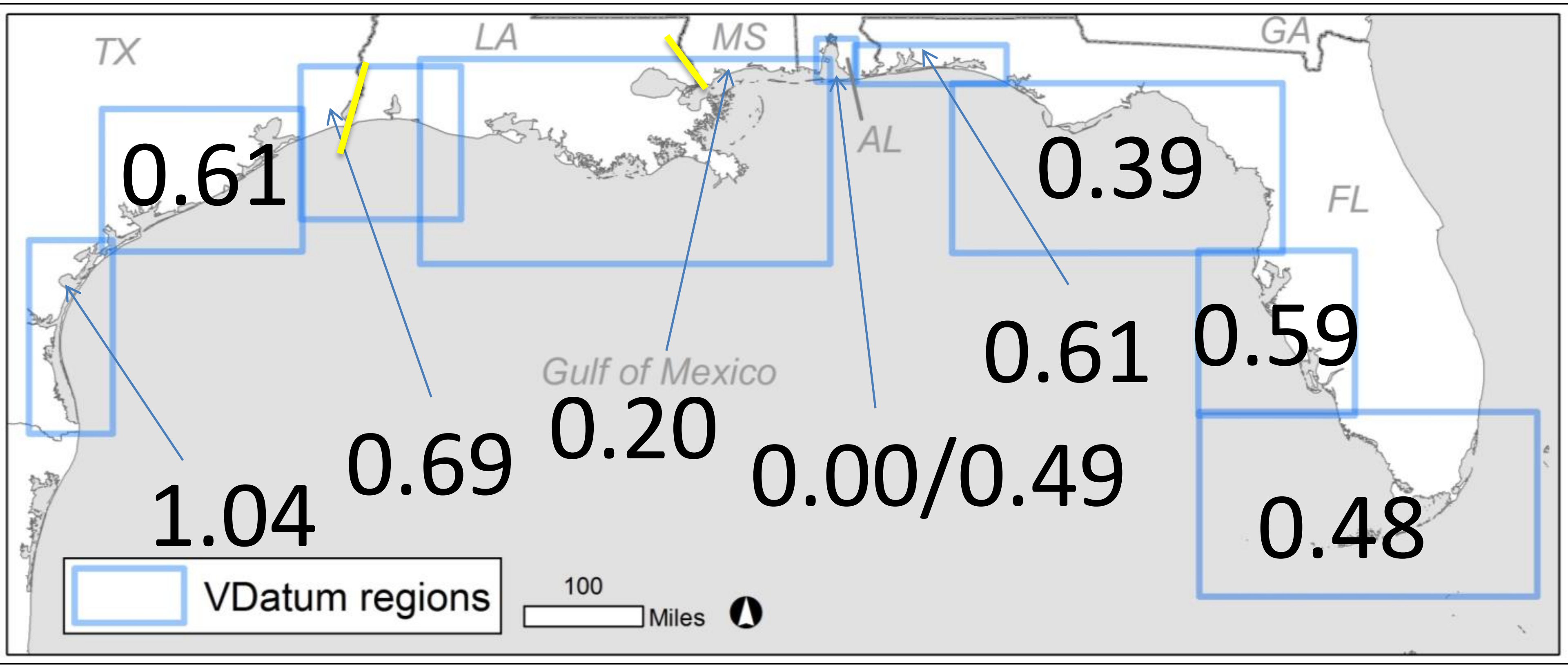
Our approach: data driven

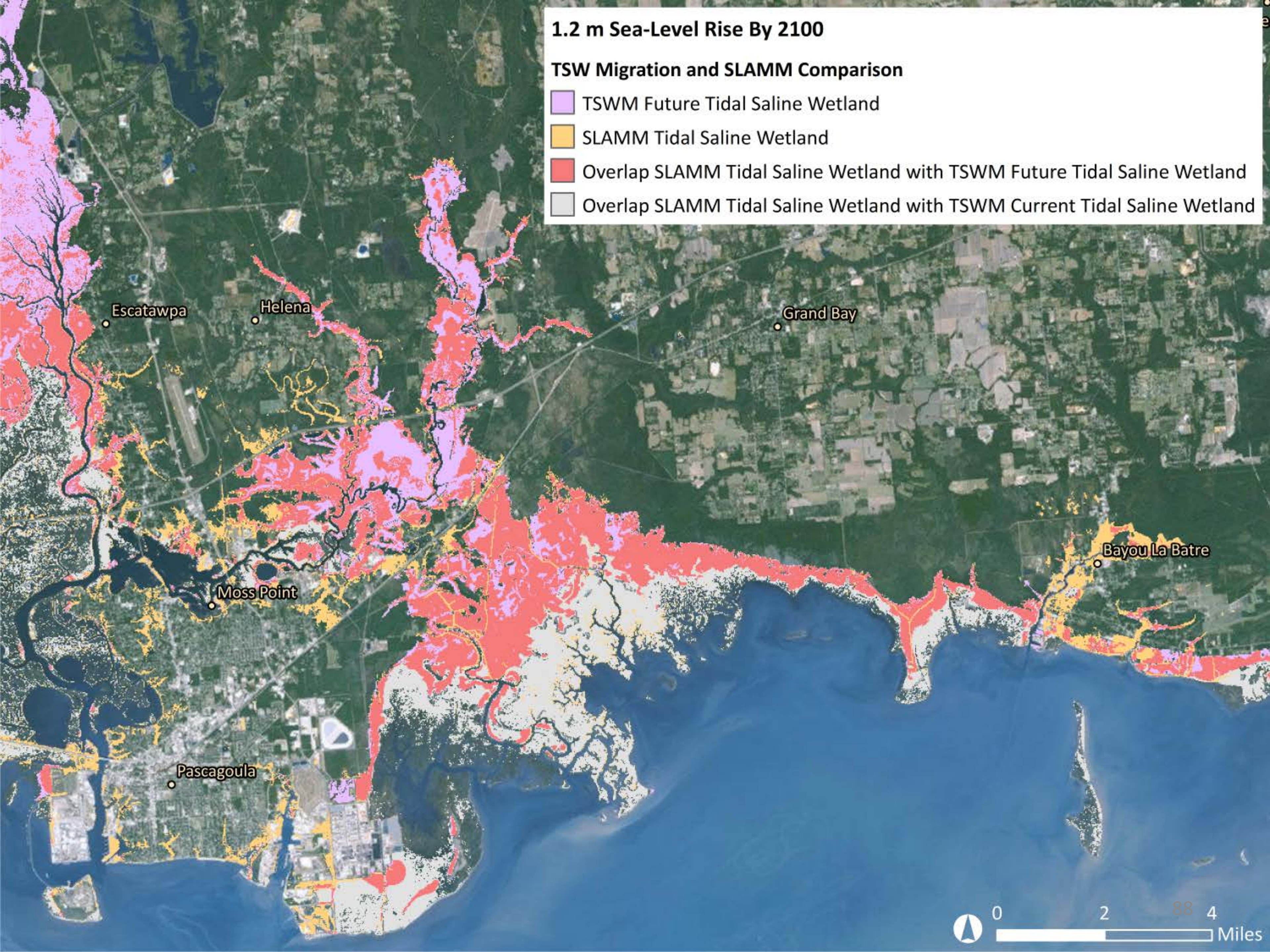


Model regions



Change point analysis results (threshold values; unit = m above MHHW)




1.2 m Sea-Level Rise By 2100
TSW Migration and SLAMM Comparison
TSWM Future Tidal Saline Wetland
SLAMM Tidal Saline Wetland
Overlap SLAMM Tidal Saline Wetland with TSWM Future Tidal Saline Wetland
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2
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