Estuarine Shoreline Erosion and Coastal Hazards of North Carolina a Globally Changing Climate

Reide Corbett and J.P. Walsh

Geological Sciences and

the Institute for Coastal Sciences and Policy

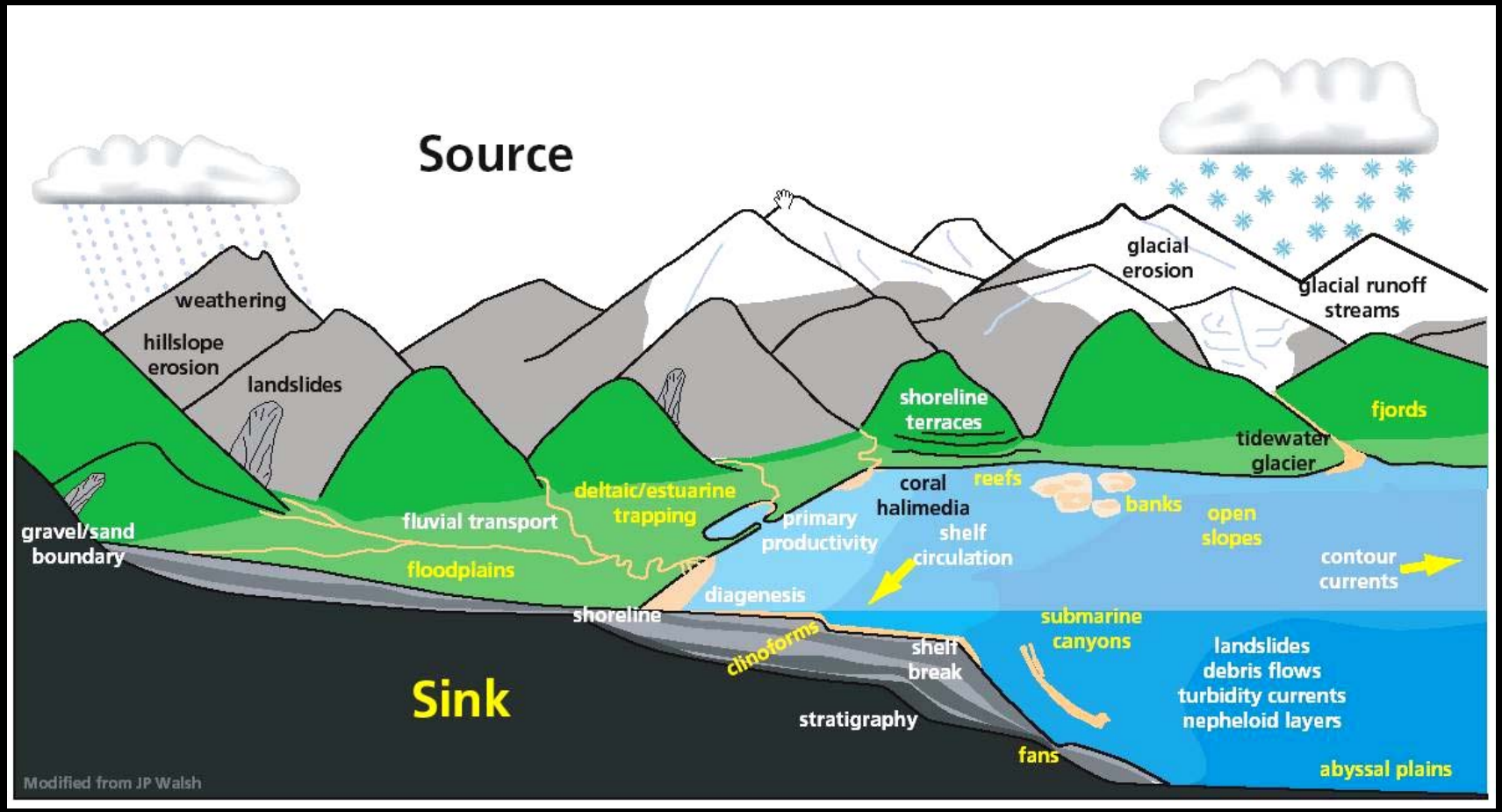
East Carolina University

East Carolina University
1907-2007 CENTENNIAL

Acknowledgements: Lisa Cowart, David Kunz, Mark Brinson, Bob Christian, Ben Horton, Stan Riggs, Steve Culver, Dave Mallinson, and many others.

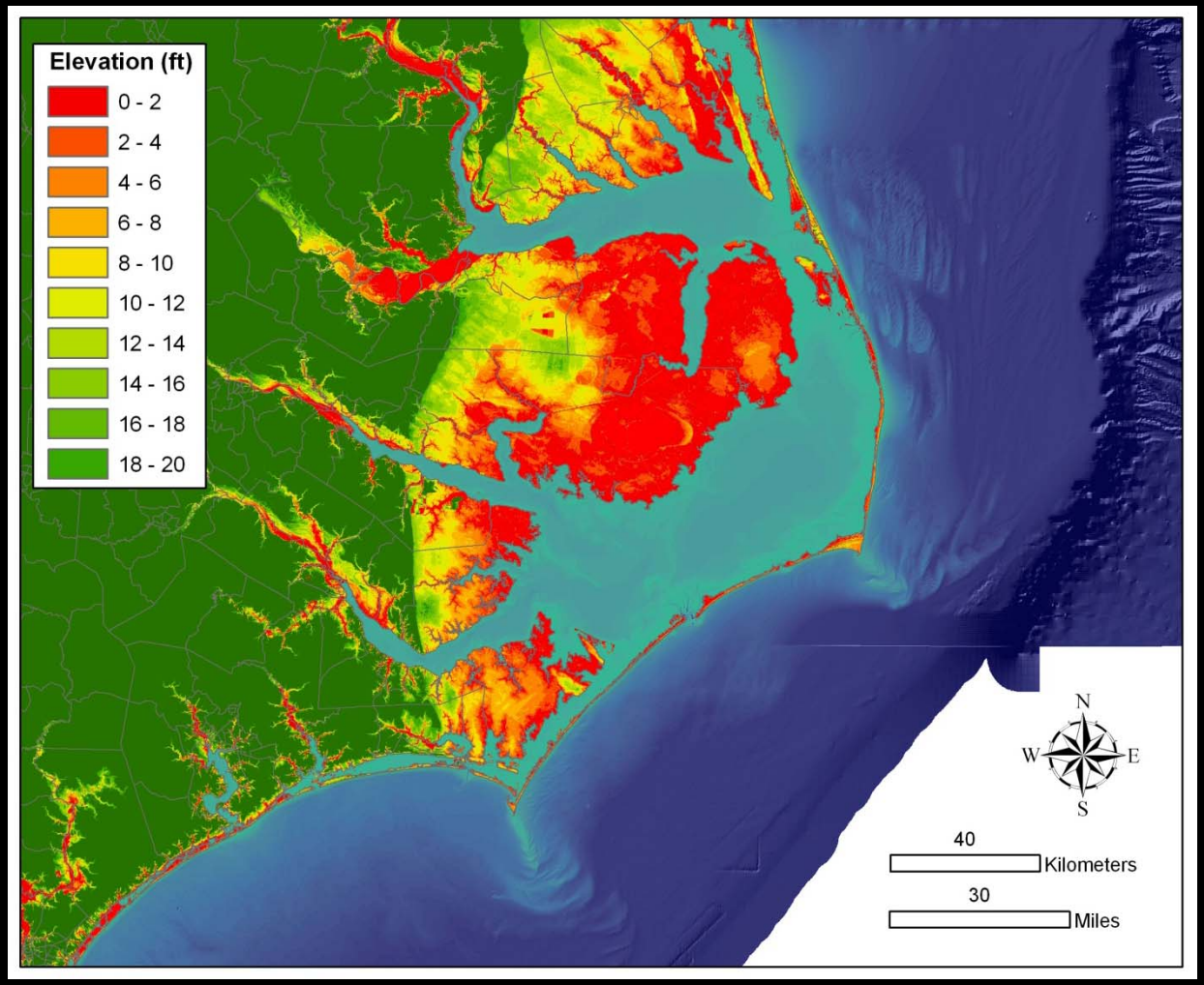
My Background

- B.A. Colgate Univ., M.S. Stony Brook, Ph.D. Univ. of Washington, Post Doc Scripps Inst. of Oceanography
- Joint-appointed Assistant Professor in Geological Sciences and ICSP at ECU.
- Interested in land-sea interactions and coastal hazards.
- Use variety of tools to map, analyze and understand dynamics and impacts.
- Shorezone to deep seafloor. New Bern to New Zealand.



Why care about climate change affects on the NC coast?

- Coastal NC has a massive area <2 ft above sea level.
- This region is an important economic engine for the state.
- Critical, sensitive habitats occupy the coastal region (e.g., estuaries).



Why plan for climate change and coastal hazards?

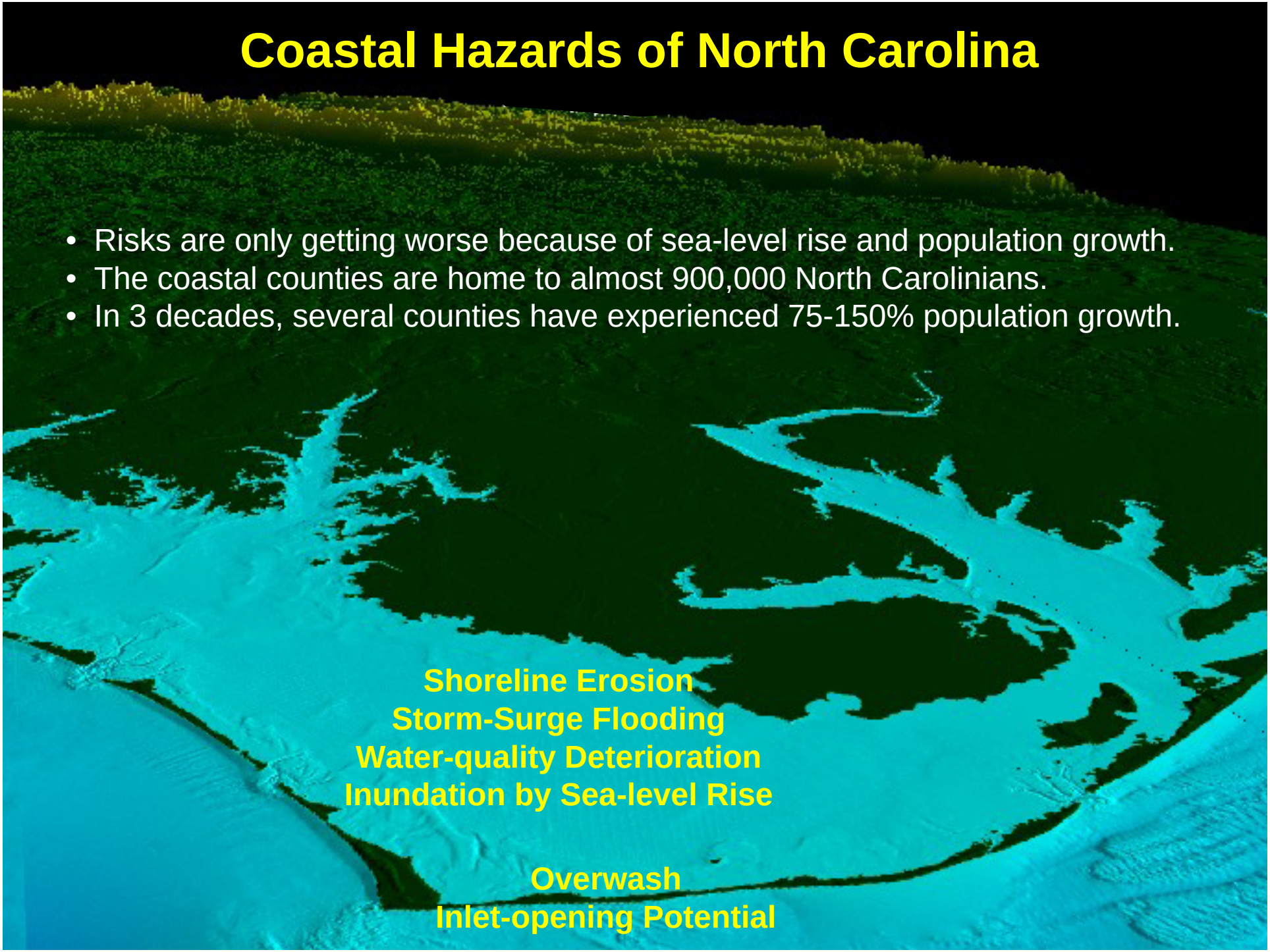
- **Without a healthy environment our coastal tourism and fisheries will suffer.**
- **Visitors to coastal counties spent over $2.5 billion in 2007, over 15% of the state's total tourism dollars that.**
- **Not having appropriate plans, infrastructure and responses could be costly.**






Assortment of photographs from the internet.

Coastal Hazards of North Carolina



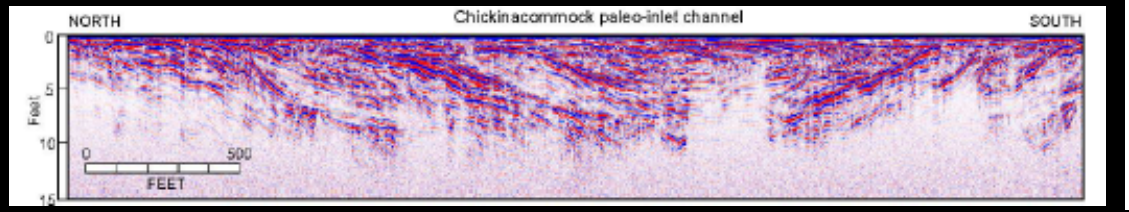
- Risks are only getting worse because of sea-level rise and population growth.
- The coastal counties are home to almost 900,000 North Carolinians.
- In 3 decades, several counties have experienced 75-150% population growth.

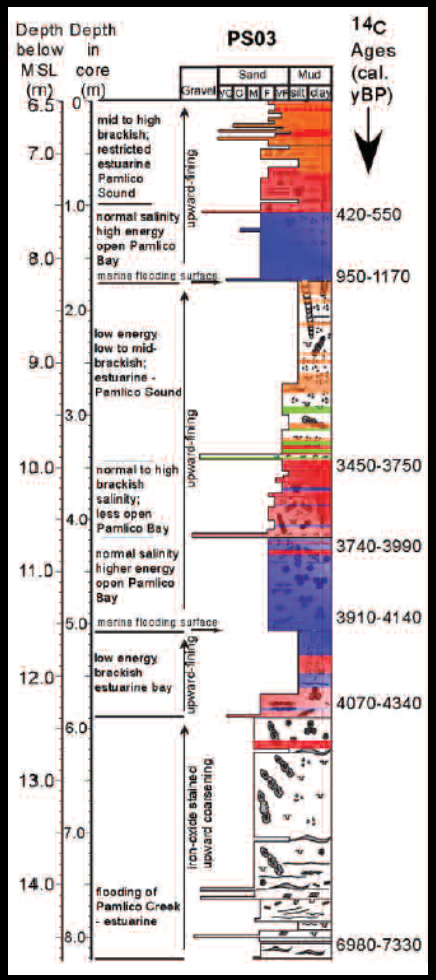
Shoreline Erosion
Storm-Surge Flooding
Water-quality Deterioration
Inundation by Sea-level Rise

Overwash
Inlet-opening Potential

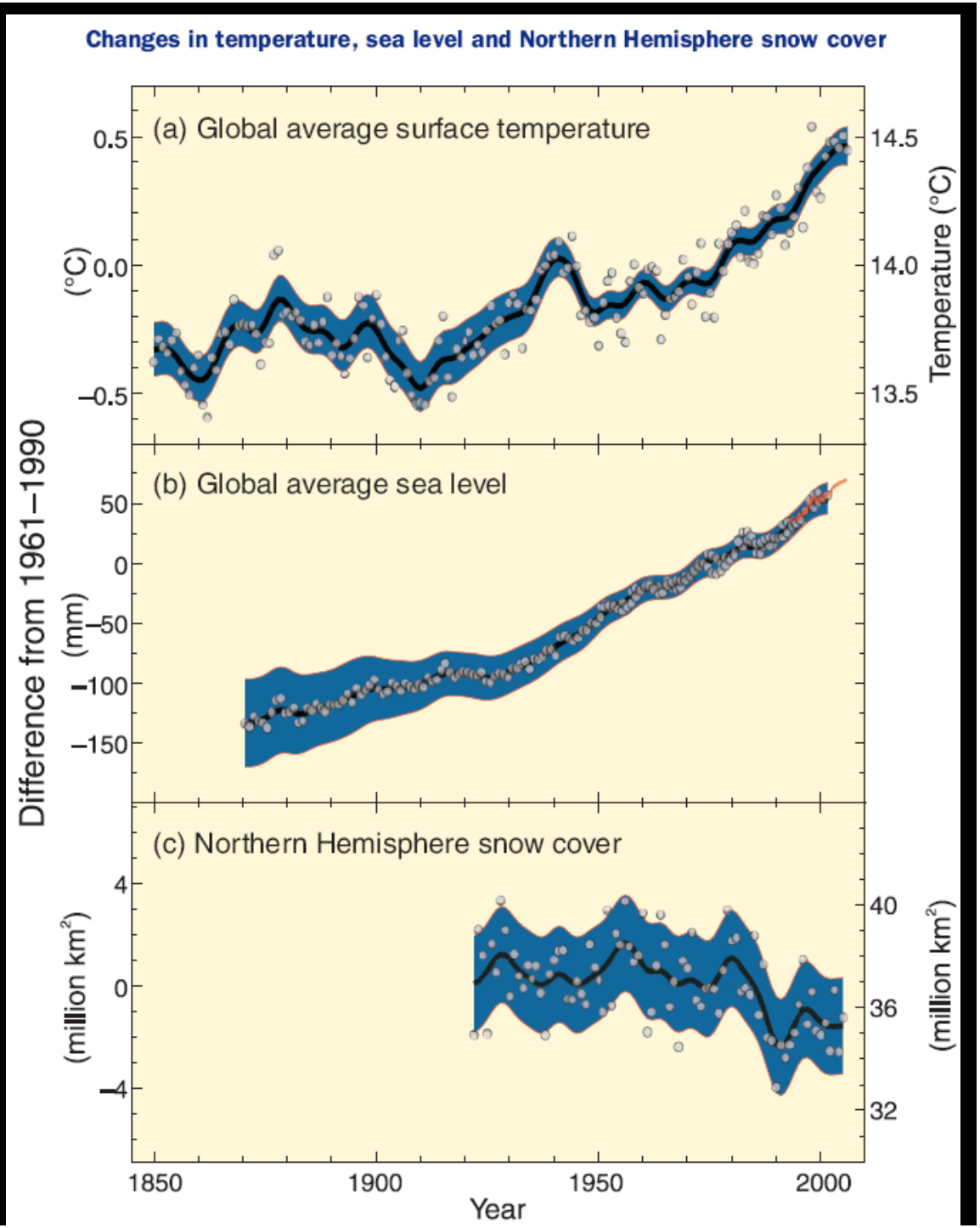
Recent Coastal Hazards Projects at ECU

- USGS
- NOAA
- NSF
- UNC Competitiveness
- RENCI
- ECU



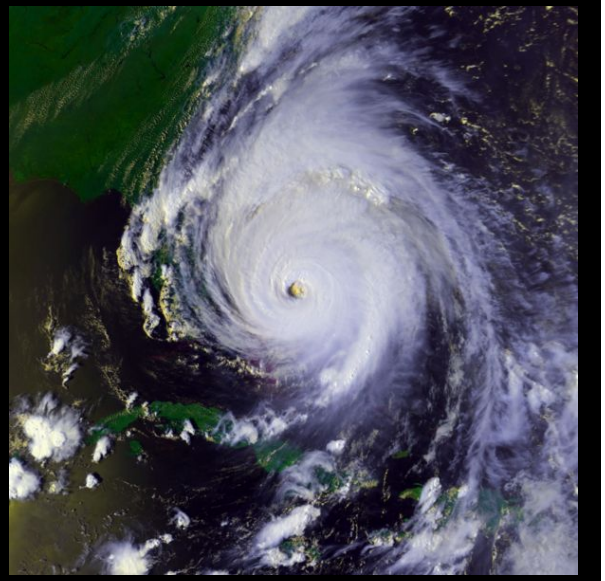


The climate is changing causing other environmental consequences.
(IPCC, 2007)



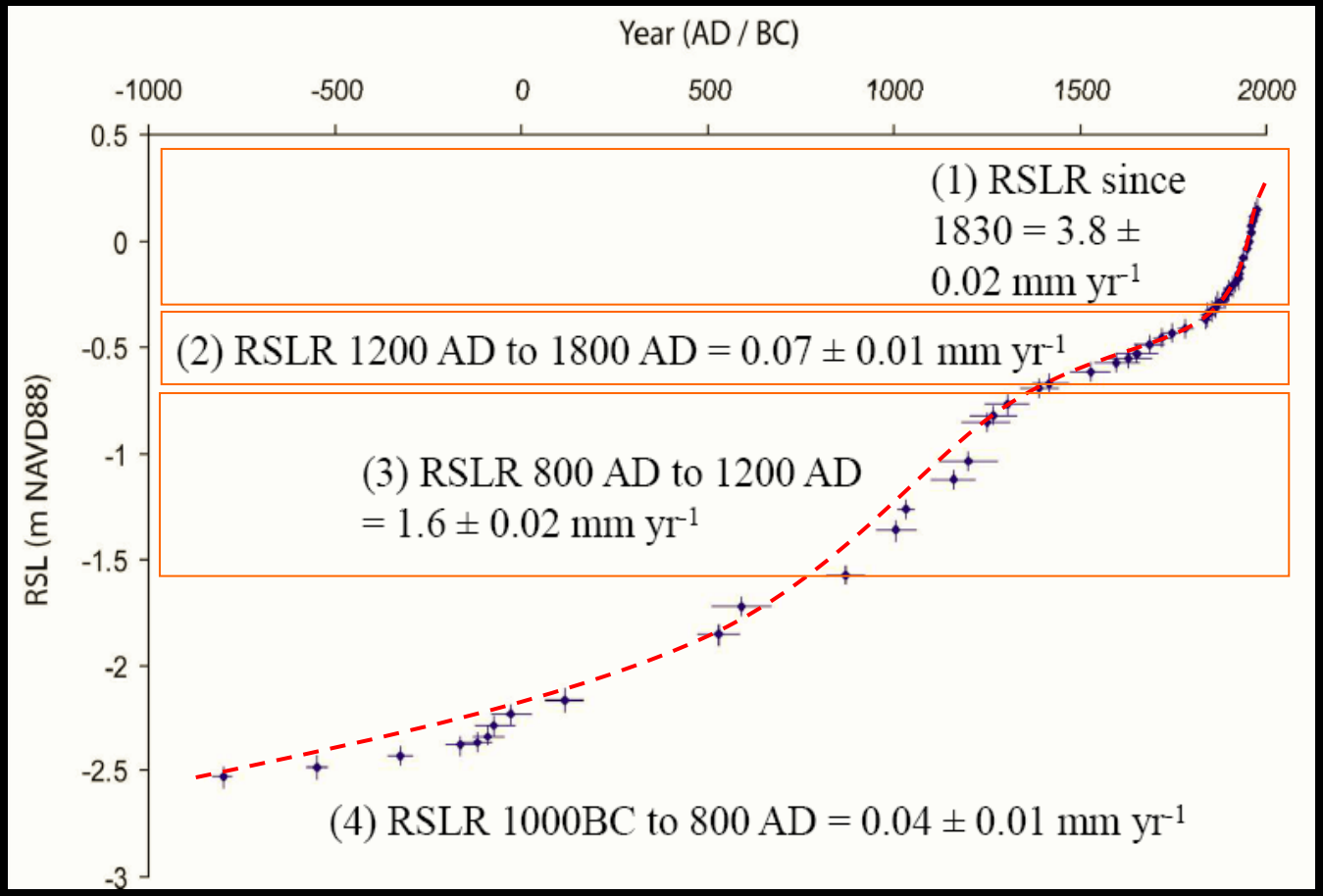
Consequences of Climate Change in NC

- Sea-level Rise
- Storms
- Droughts
- Floods
- Land and habitat loss
- Ecological effects
- Economic impacts



Sea-Level Rise

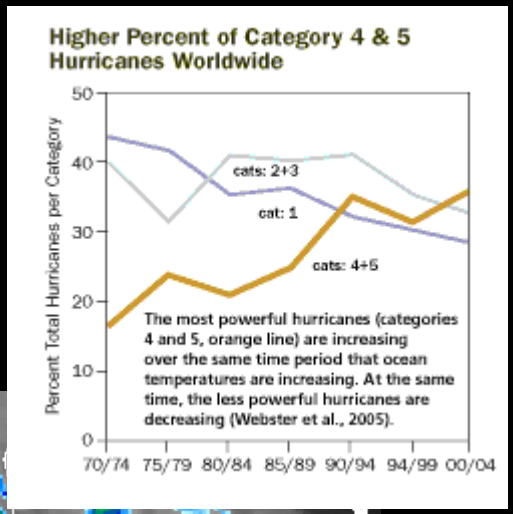
- Slow, chronic process
- Possibly accelerating

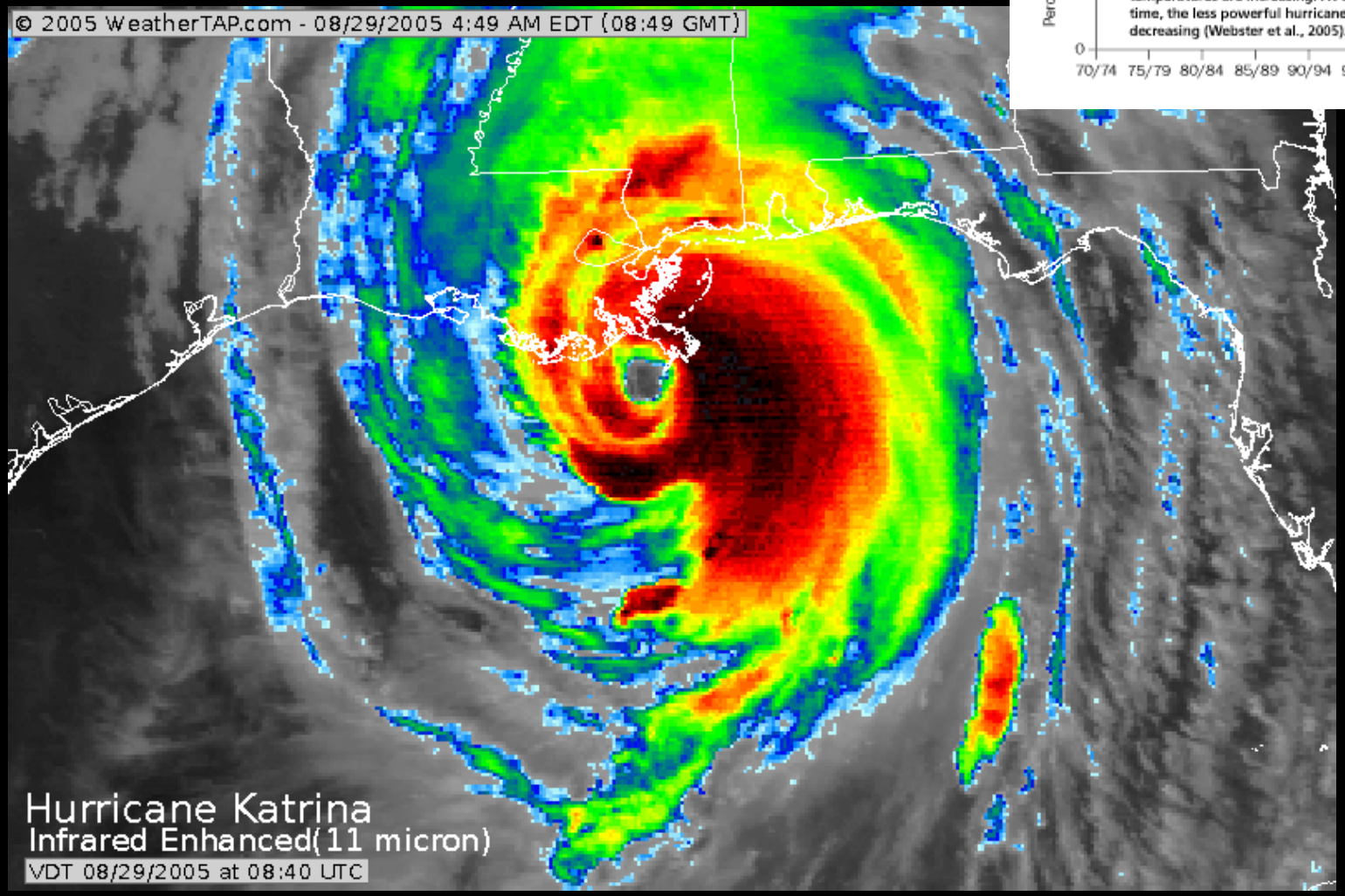


Microfossil and radionuclide data suggest a pronounced change in the rate of SLR.

Storms

- Episodic, Acute
- More frequent intense hurricanes





North Carolina's Intellectual Capital

- Sea-level Rise
- Storm Surge
- Barrier Island Processes
- Ocean Shoreline Erosion
- Estuarine Shoreline Erosion
- Land-use change
- Management
- Nutrient dynamics
- Hypoxia/Anoxia
- Coastal ocean observing
- Remote Sensing
- Marsh
- Oyster
- Fisheries
- Blue Crab
- Resource economics
- Human aspects
- Tourism
- Water resources
- Cultural resources

East Carolina University
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NORTH CAROLINA Wildlife RESOURCES COMMISSION

NORTH CAROLINA MARINE FISHERIES

NCDENR

NC DIVISION OF COASTAL MANAGEMENT

UNCW

Sea Grant North Carolina

DUKE

ELIZABETH CITY ECSU STATE UNIVERSITY

NORTH CAROLINA AQUARIUMS

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

GEOLOGICAL SURVEY N.C. 1823

NC COHAZ Decision Portal is a web-based information system developed to communicate coastal hazards information to North Carolina's coastal communities. It is a one-stop site for useful data, observations and insights on coastal hazards.

Goals of NC COHAZ:

1) **Provide a basic review of and information for coastal hazards in NC, including emergency contacts, hazard mitigation plans, important web sites.**

2) **Create tools to enable the public, managers and scientists to visualize hazard areas and impacts from past events.**

3) **Give brief explanation of and access to relevant natural and social science data.**

Navigation:

- About
- People
- Maps & Visualizations
- Hazard Information
- Mitigation Plans
- Emergency Info
- Hazards Glossary
- UNC Project
- Links
- Home

- Disclaimer

Supported By:

EAST CAROLINA UNIVERSITY

Renci Renaissance Computing Institute

0008701 NCCOHAZ Visitor Count

Cape Hatteras, NC

FOG 64° F

Fog

Hour-by-hour | 10-day

Enter city or U.S.zip GO

QUICK LINKS: CURRENT HAZARDS | Watches, Warnings & Forecasts | Active Hurricanes

NC coastal hazards in the news...

posted 10/23/2008

ANOTHER STORM BATTERS THE COAST: This week's coastal storm has caused more overwash and erosion along the OBX. DOT crews have had to work hard to maintain HWY 12 which closed briefly. Rodanthe and its famous home have incurred damage.

Story and video provided by: The Virginian Pilot

Another story by: The Island Free Press

Graphic Slideshow: Don Bowers Slideshow

previous news...

North Carolina's coasts are in crisis. Read the recent report...

posted 10/16/2008 Stan Riggs and colleagues at ECU have put together a nicely illustrated brochure explaining and illustrating problems facing the NC coasts. Inlet-opening is one hazard discussed (shown at right) Download and read this report by clicking here.

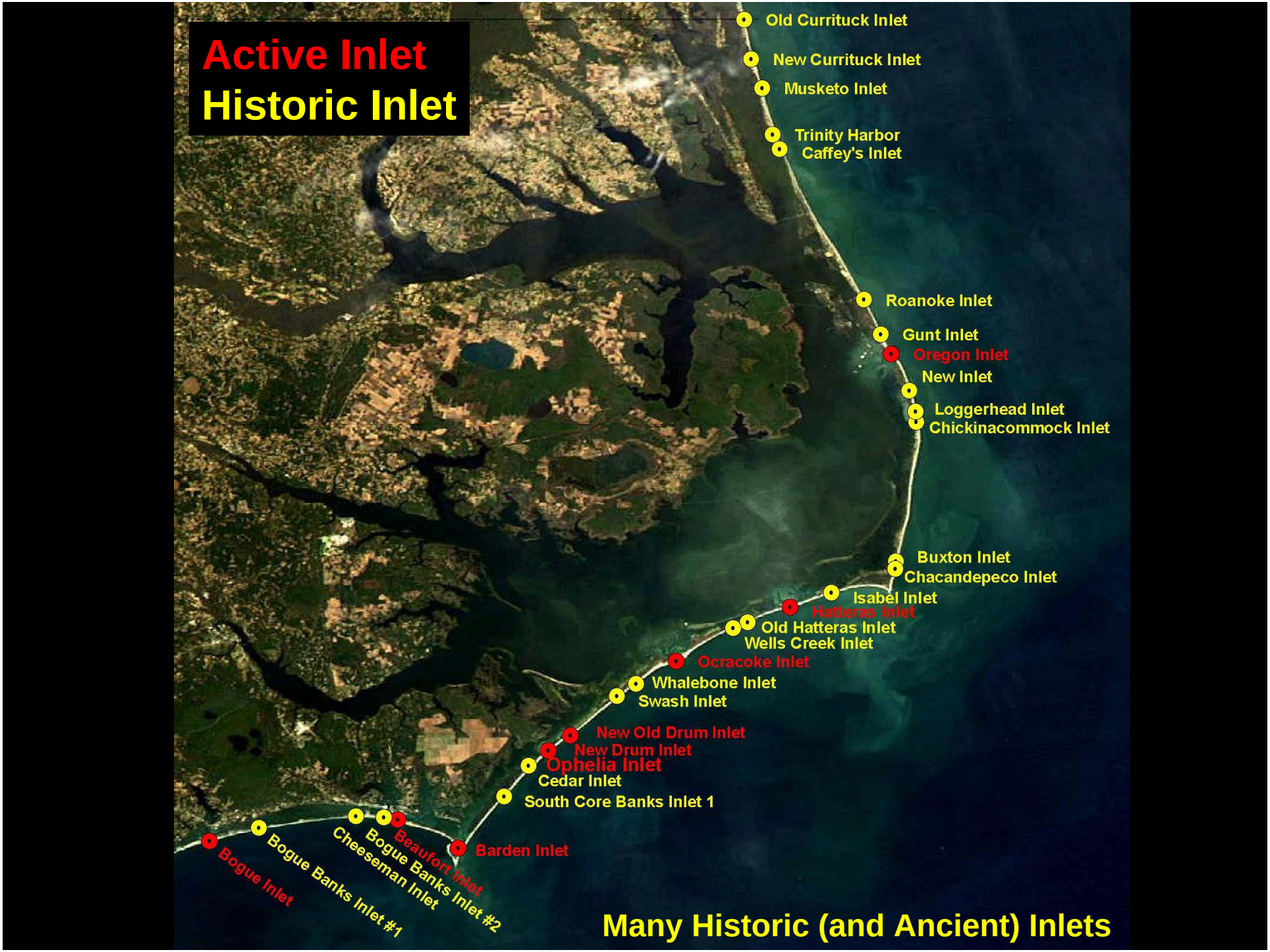
At left is an aerial photograph of Hatteras Island looking west after Hurricane Isabel in 2003. Overwash and a new inlet are visible. Photograph from USGS.

What is NC COHAZ?

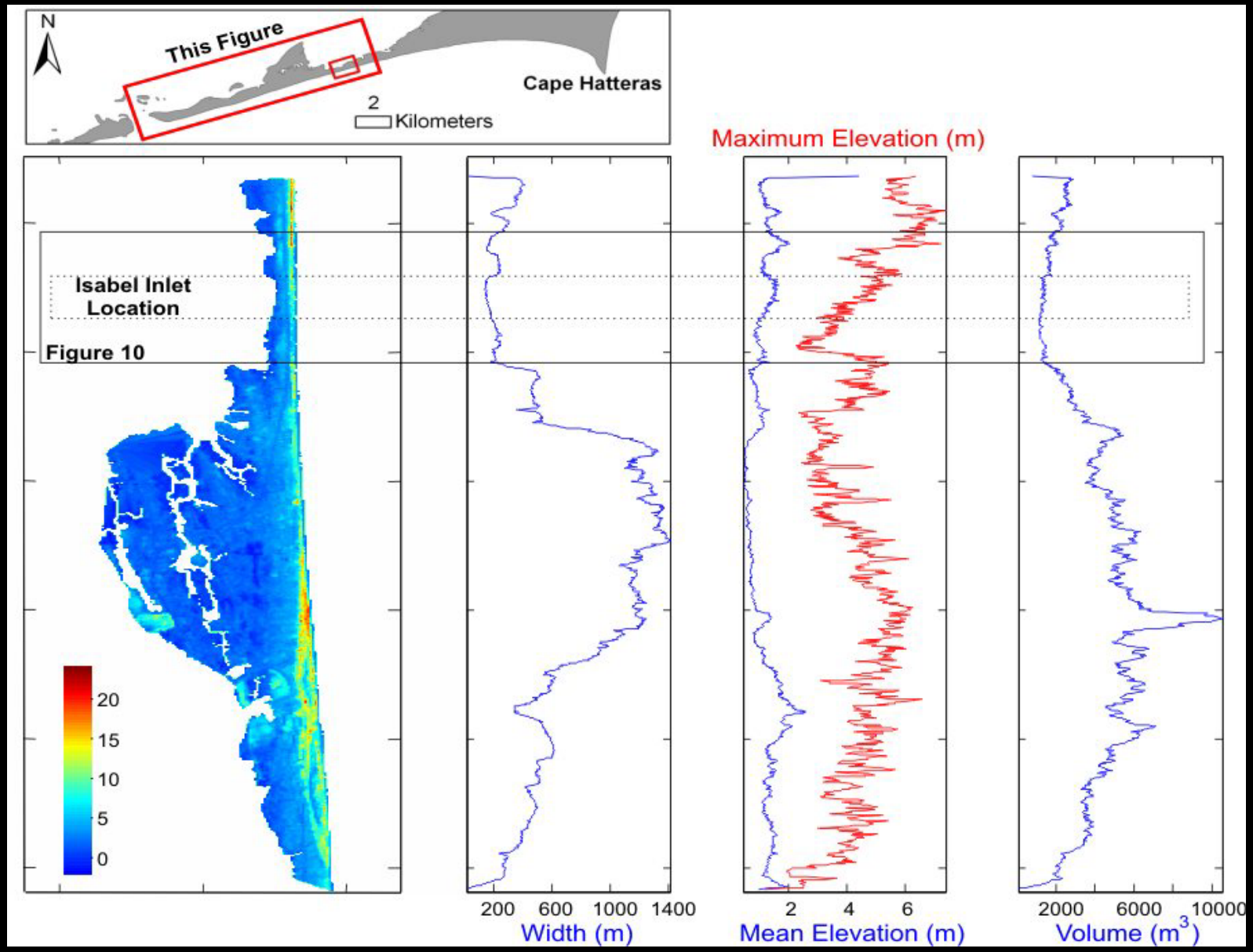
North Carolina has an extensive coastal zone where people live, work and recreate. This coastal zone is home to important human infrastructure and natural resources. Coastal hazards pose a threat to these resources and the society that uses them. The primary goal of the North Carolina COastal HAZards (NC COHAZ) Decision Portal is to distribute coastal hazards information to the

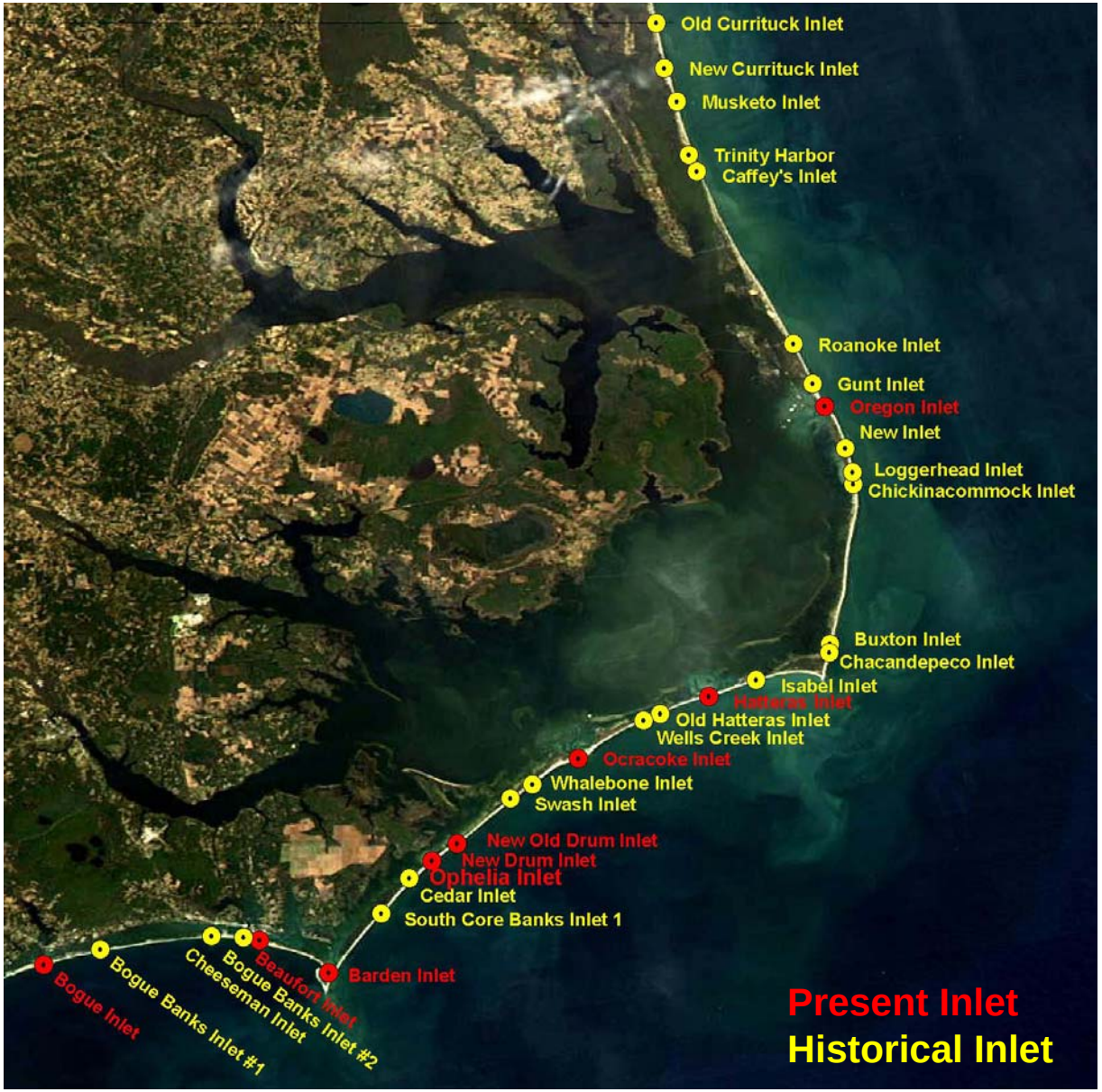
Inlet-Opening Potential

A very real coastal hazard along the OBX.


Active Inlet
Historic Inlet
Old Currituck Inlet
New Currituck Inlet
Musketo Inlet
Trinity Harbor
Caffey's Inlet
Roanoke Inlet
Gunt Inlet
Oregon Inlet
New Inlet
Loggerhead Inlet
Chickinacommock Inlet
Buxton Inlet
Chacandepeco Inlet
Isabel Inlet
Hatteras Inlet
Old Hatteras Inlet
Wells Creek Inlet
Ocracoke Inlet
Whalebone Inlet
Swash Inlet
New Old Drum Inlet
New Drum Inlet
Ophelia Inlet
Cedar Inlet
South Core Banks Inlet 1
Barden Inlet
Beaufort Inlet
Bogue Banks Inlet #2
Cheeseman Inlet
Bogue Banks Inlet #1
Bogue Inlet
Many Historic (and Ancient) Inlets

What areas along the OBX have the greatest potential for inlet opening? Why?





◯ **Inlets in last century.**

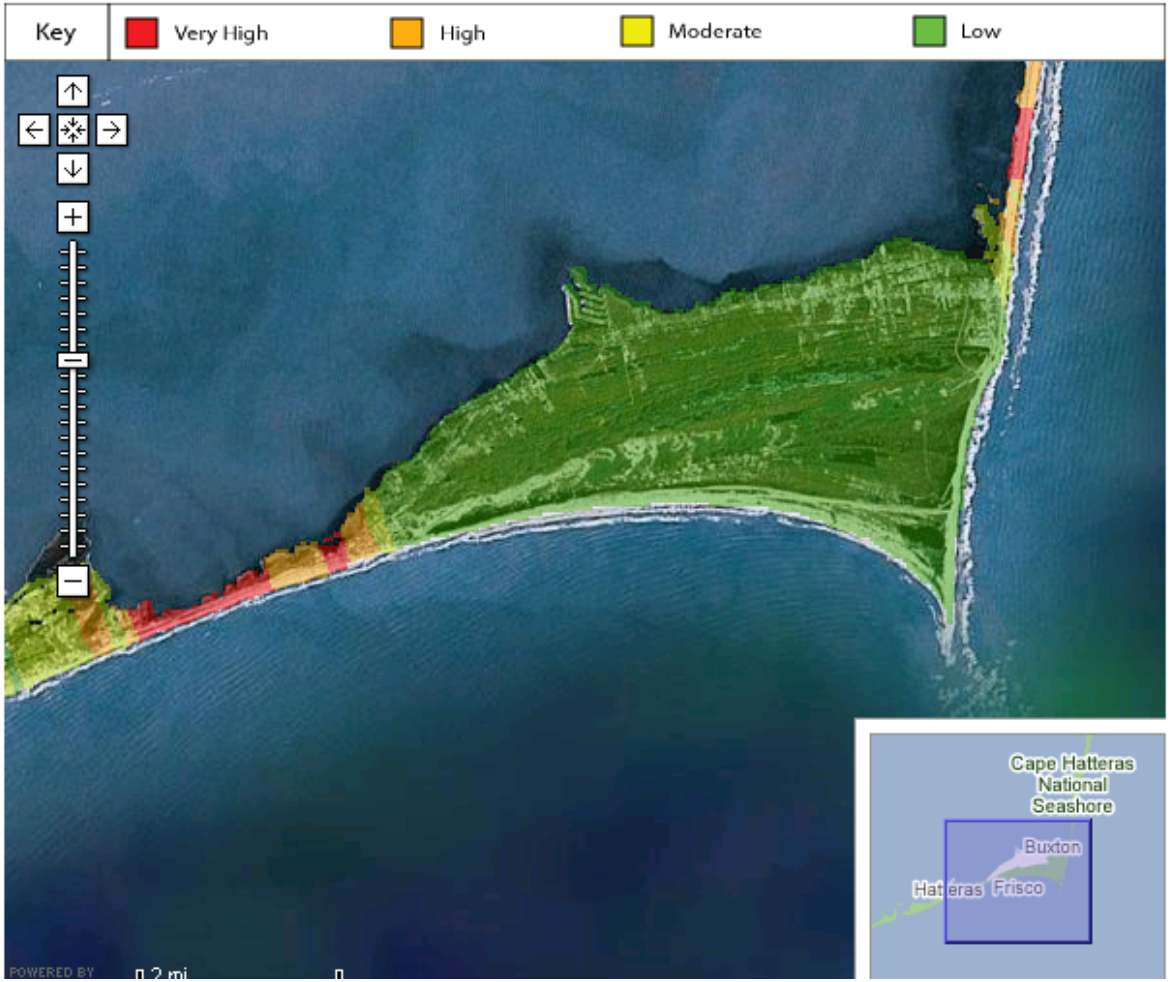
- **UNC Competitiveness**
- **Building coastal hazards database**
- **Including Google Maps viz tools**

North Carolina COastal HAZards Decision Portal

NC COHAZ

www.coastal.geology.ecu.edu/NCCOHAZ

NCCOHAZ: Inlet-Opening Potential



Inlet-Opening Potential along the Outer Banks, NC

Shown at left is the standard Google Maps "Satellite" view overlain by a transparent layer of inlet-opening potential along the Outer Banks (OBX) of North Carolina. See the key for the classification levels. Note, the transparency of the inlet-opening-potential layer can be adjusted using the sliding bar at the bottom of the view. The data, where available, highlight the areas with greatest potential for the opening of an inlet during a major storm. Because the opening of an inlet will sever the major transportation route (i.e., Highway 12) along the OBX, such an event is expected to have complicating effects along the OBX as occurred during Hurricane Isabel in 2003. Although many factors are hypothesized to affect inlet opening, the approach used to quantify the hazard is accurate, simple and straightforward, using cross-section measurements of the island volume above sea level (Perkins et al., 2007; Walsh et al., submitted).

Directions for use:
-Use the zoom tool to adjust the focus area.
-Use arrows or click and drag mouse to pan the view.
-Adjust layer transparency with slide bar below map.
NOTE: Page best viewed using **Mozila Fire Fox 2.0.**

Click a link below to navigate to a specific town

Avon
Buxton
Frisco
Hatteras Village
Kill Devil Hills
Kitty Hawk
Nags Head
Rodanthe
Salvo
Southern Shores
Waves

EAST CAROLINA UNIVERSITY

Built using the new Google Maps API
Question, Comments, Concerns? Contact Us

Potential Economic Impact of Inlet Opening

- **Using simple assumptions**
- **Sites shown at right**

(Vogelsong, 2008; report available on NC COHAZ)

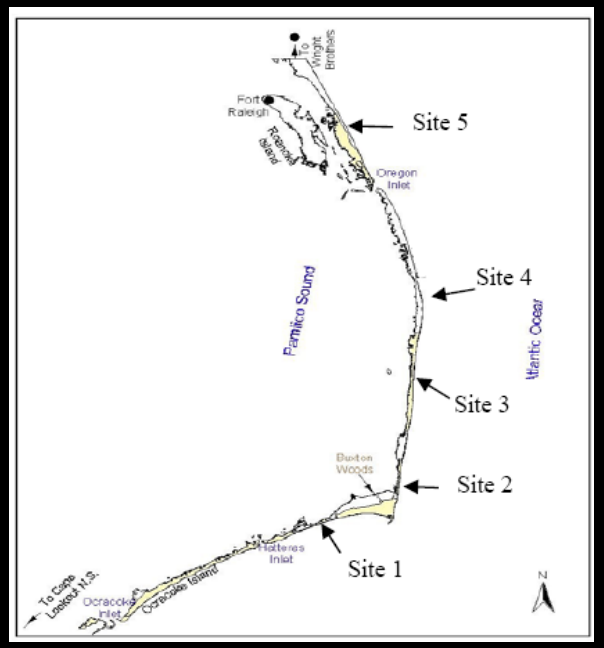


Table 2 Daily Economic Impacts

Site	Direct Impacts	Indirect Impacts	Induced Impacts	Total Impacts
1	$896,967.68	136,554	135,532	$1,169,054.68
2	$1,357,793.92	206,710	205,163	$1,769,668.92
3	$2,282,174.72	347,437	344,837	$2,974,451.72
4	$3,636,590.72	553,633	549,489	$4,739,716.72
5	$4,222,529.92	642,836	638,024	$5,503,394.92

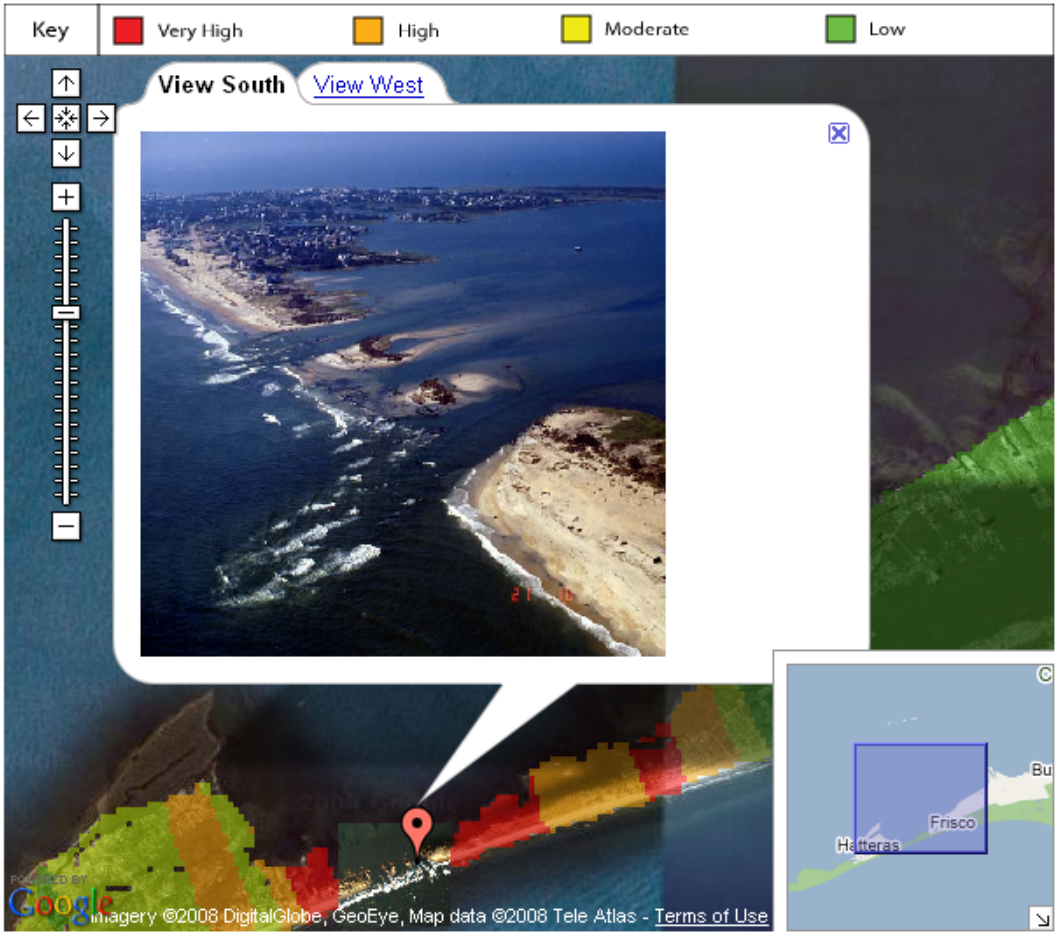
Previous Formed Inlets along the Outer Banks, NC - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://coastal.geology.ecu.edu/NCCOHAZ/maps/old_inlet.html

Google Search

NCCOHAZ: Previously Formed Inlets



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Legend / Toggles

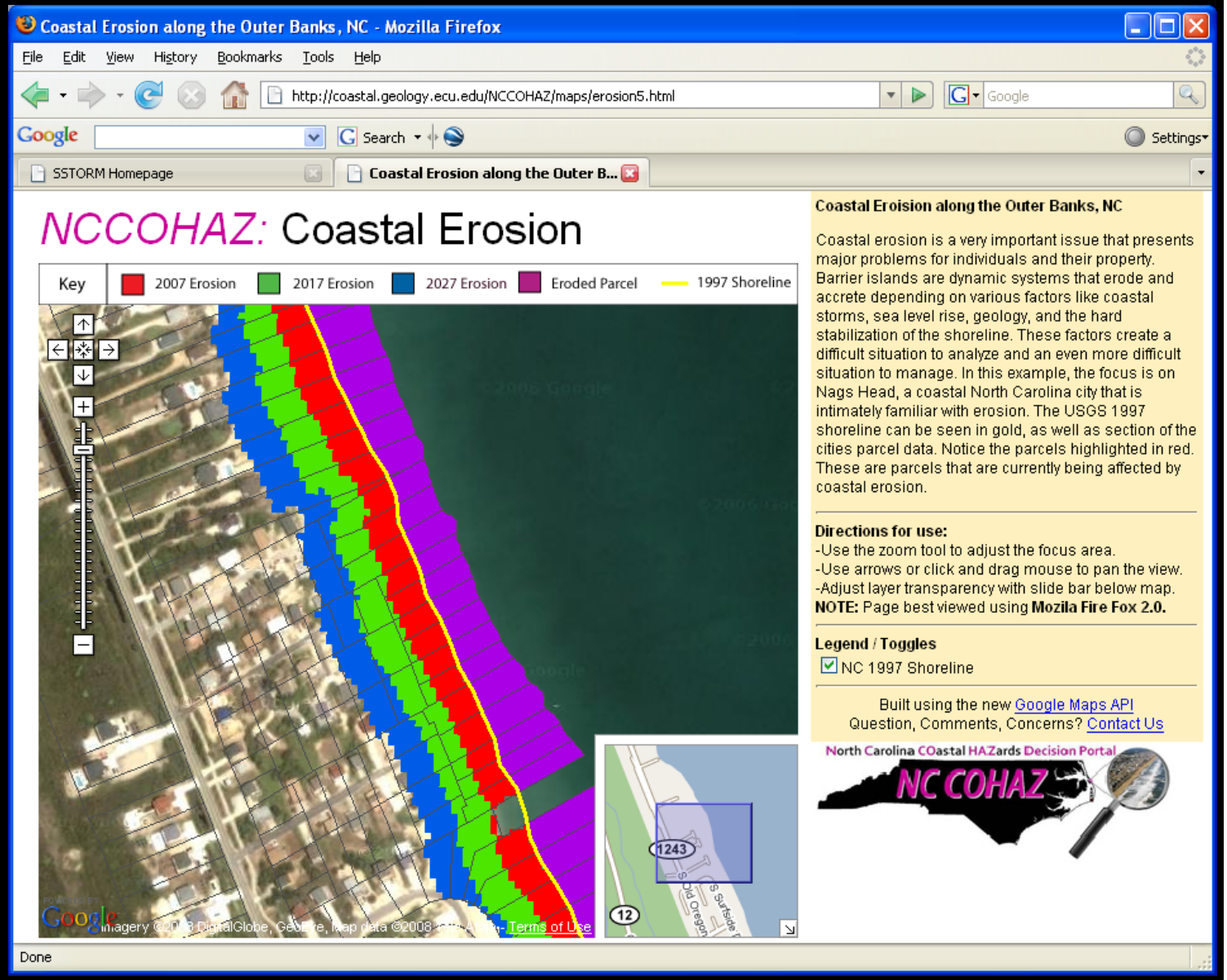
- [x] Former Inlets
- [x] Inlet Potential
- [x] Ground Penetrating Radar
- [x] Isabel Inlet Aerial Photo

Built using the new Google Maps API
Question, Comments, Concerns? Contact Us

North Carolina COastal HAZards Decision Portal
NC COHAZ

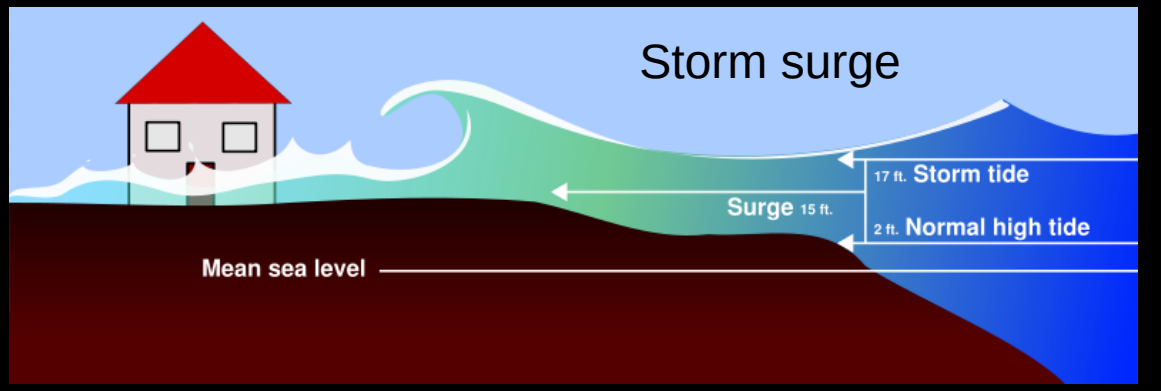
Ocean Erosion

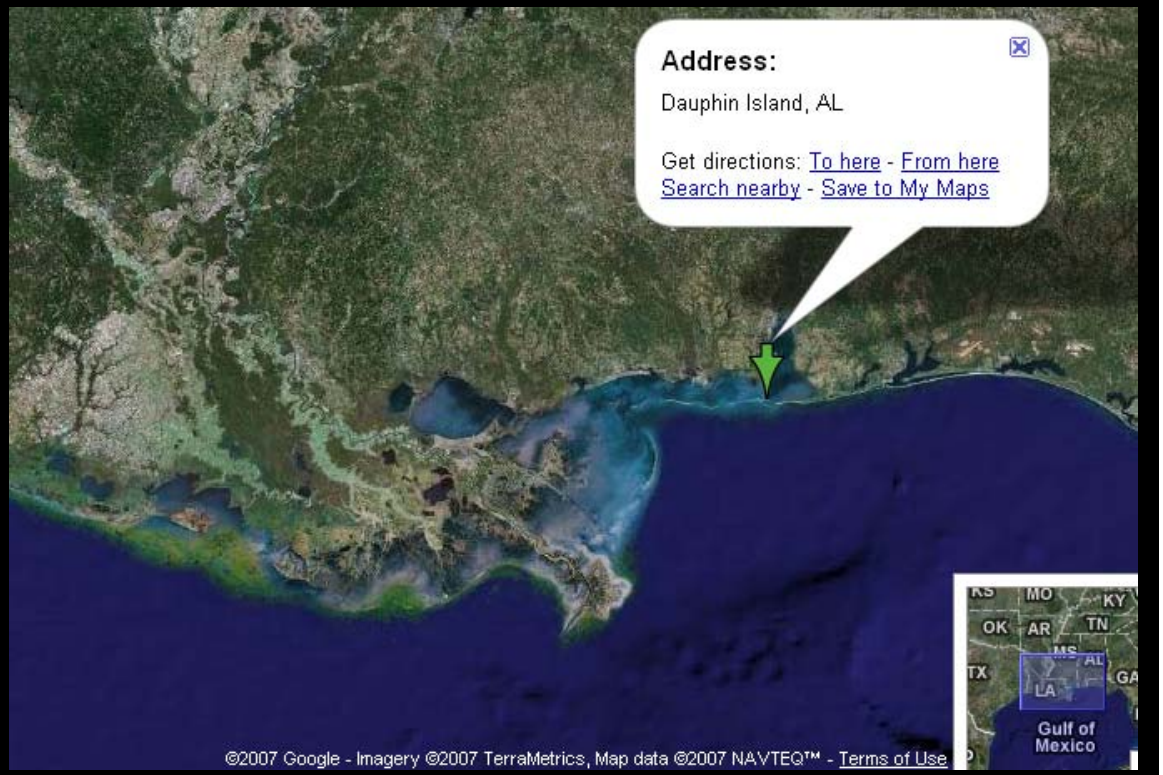
- Historical
- Recent

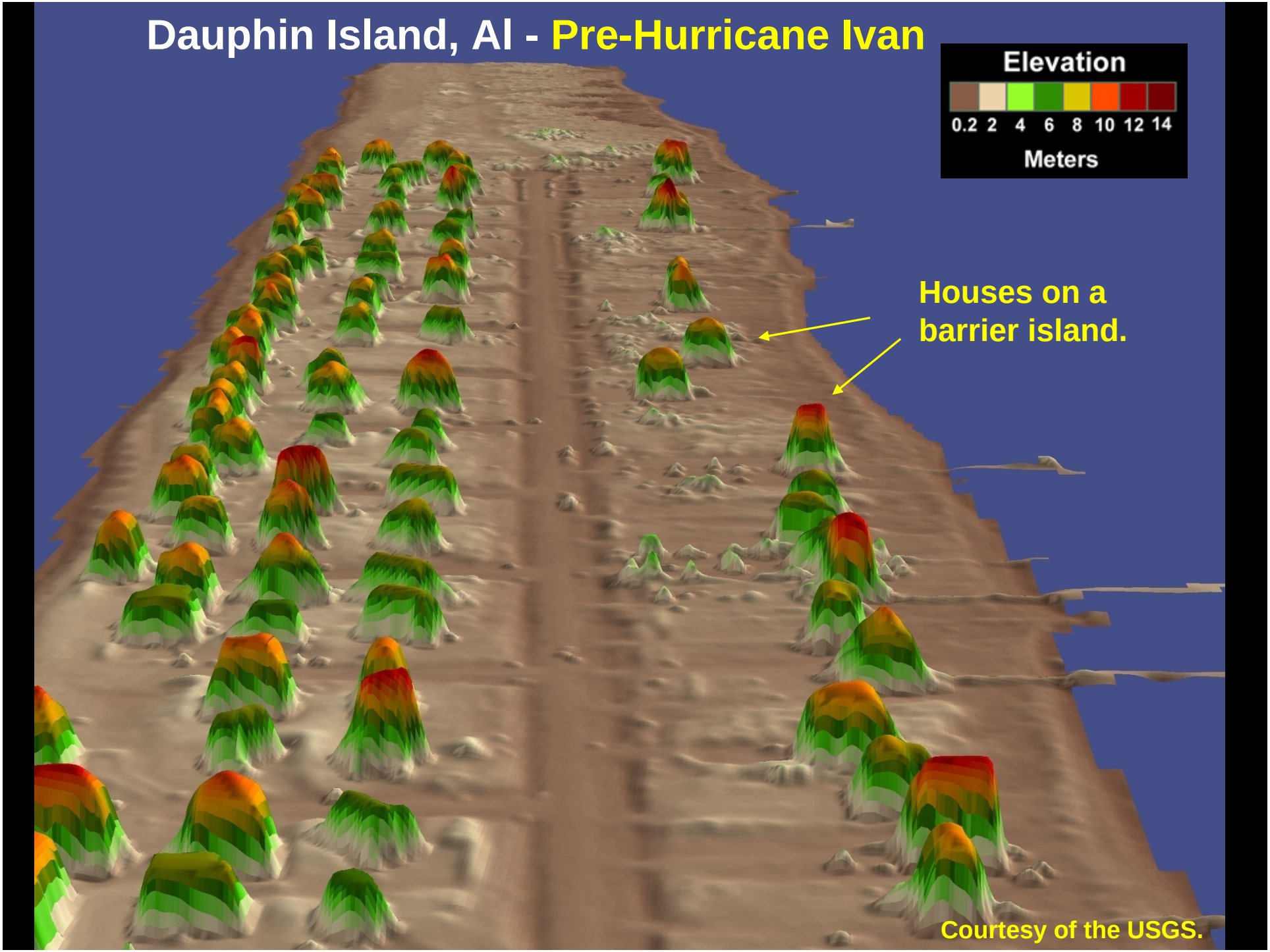


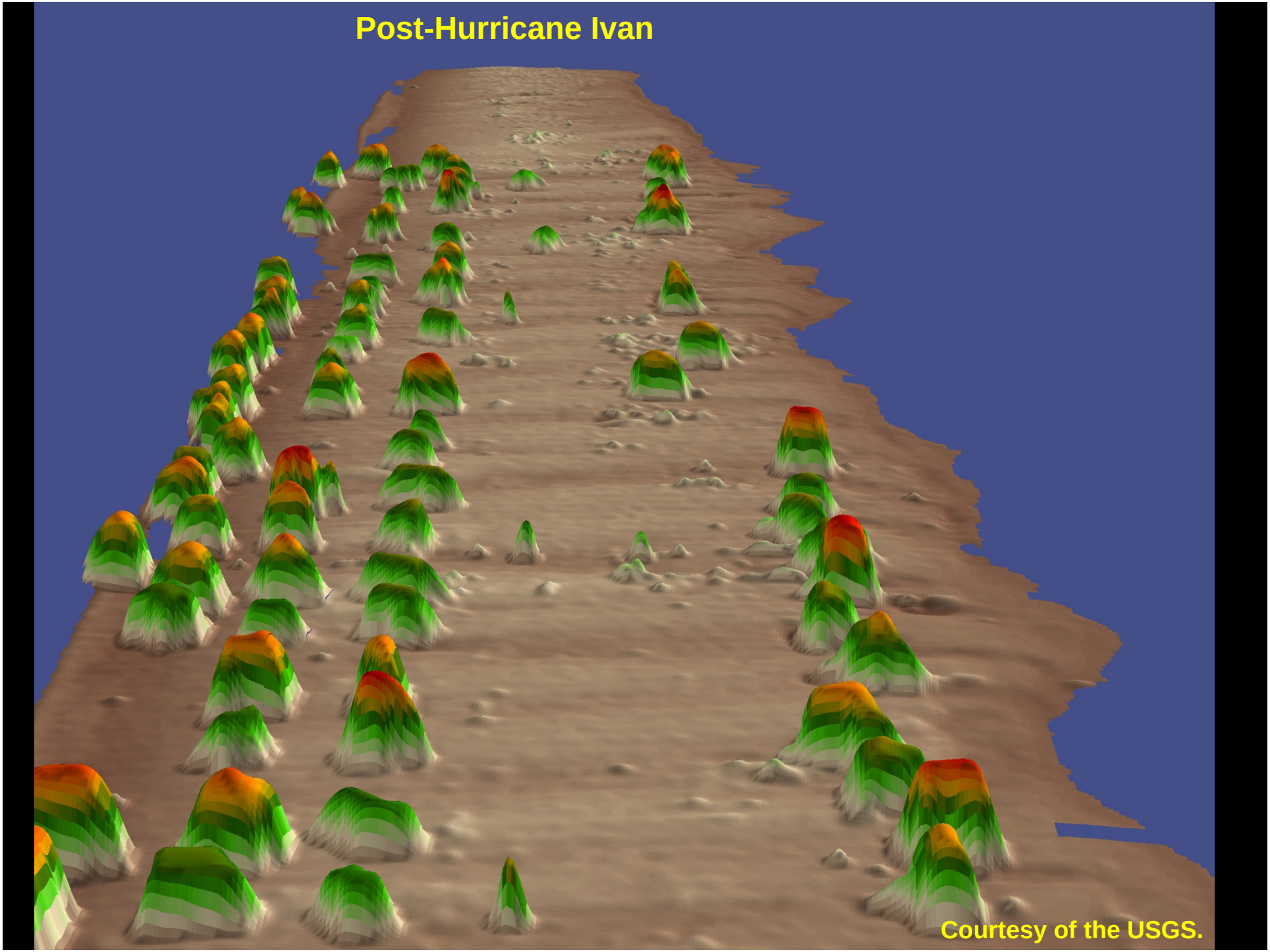
Storm Surge: A Hazard Enhanced by Climate Change

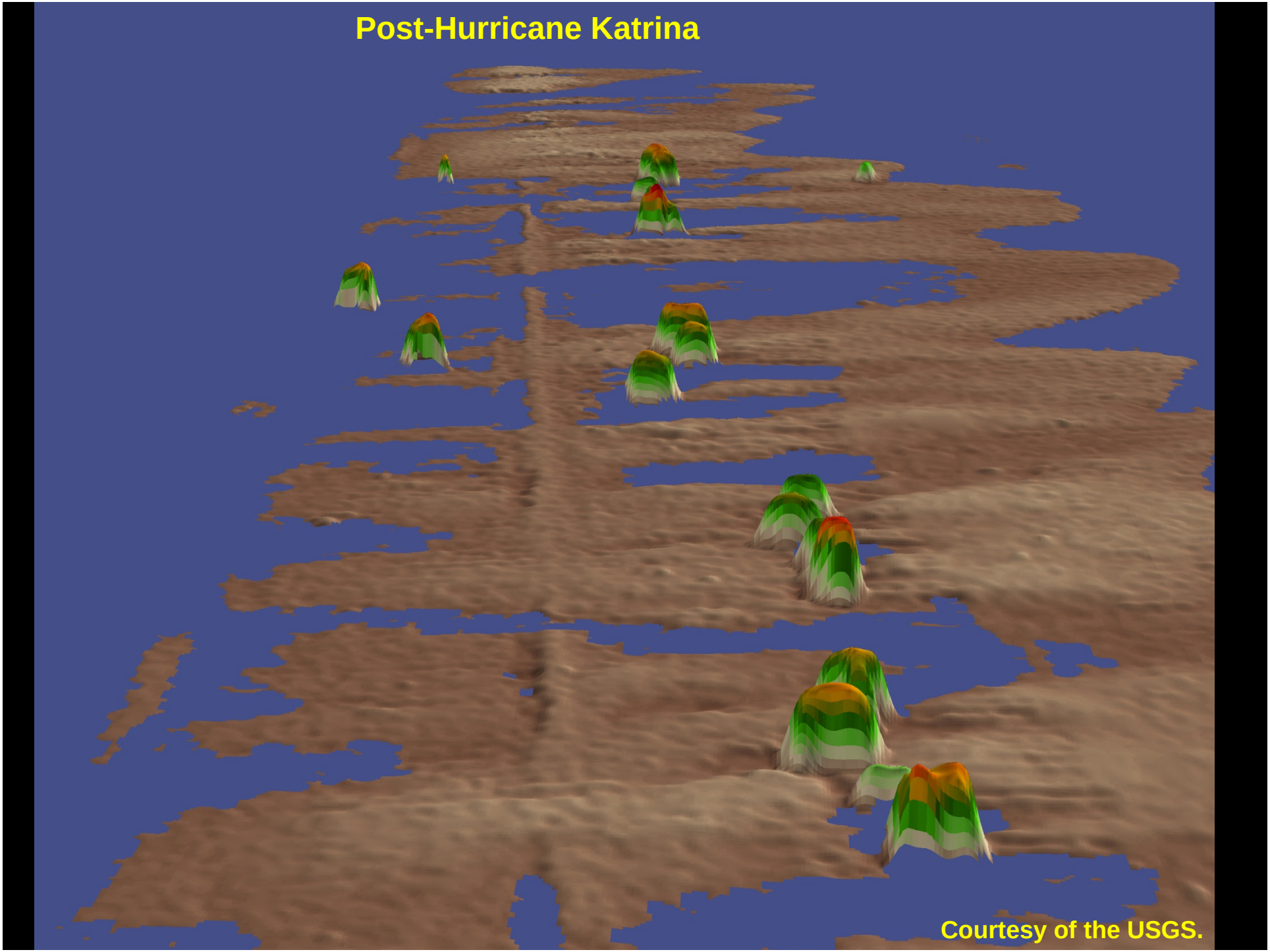
- **Learn from the past (e.g., Katrina).**
- **Adapt, prepare for the future.**
- **Have a response plan.**
- **Major hurricanes will impact the NC coast, and impacts will be worsened because of SLR.**



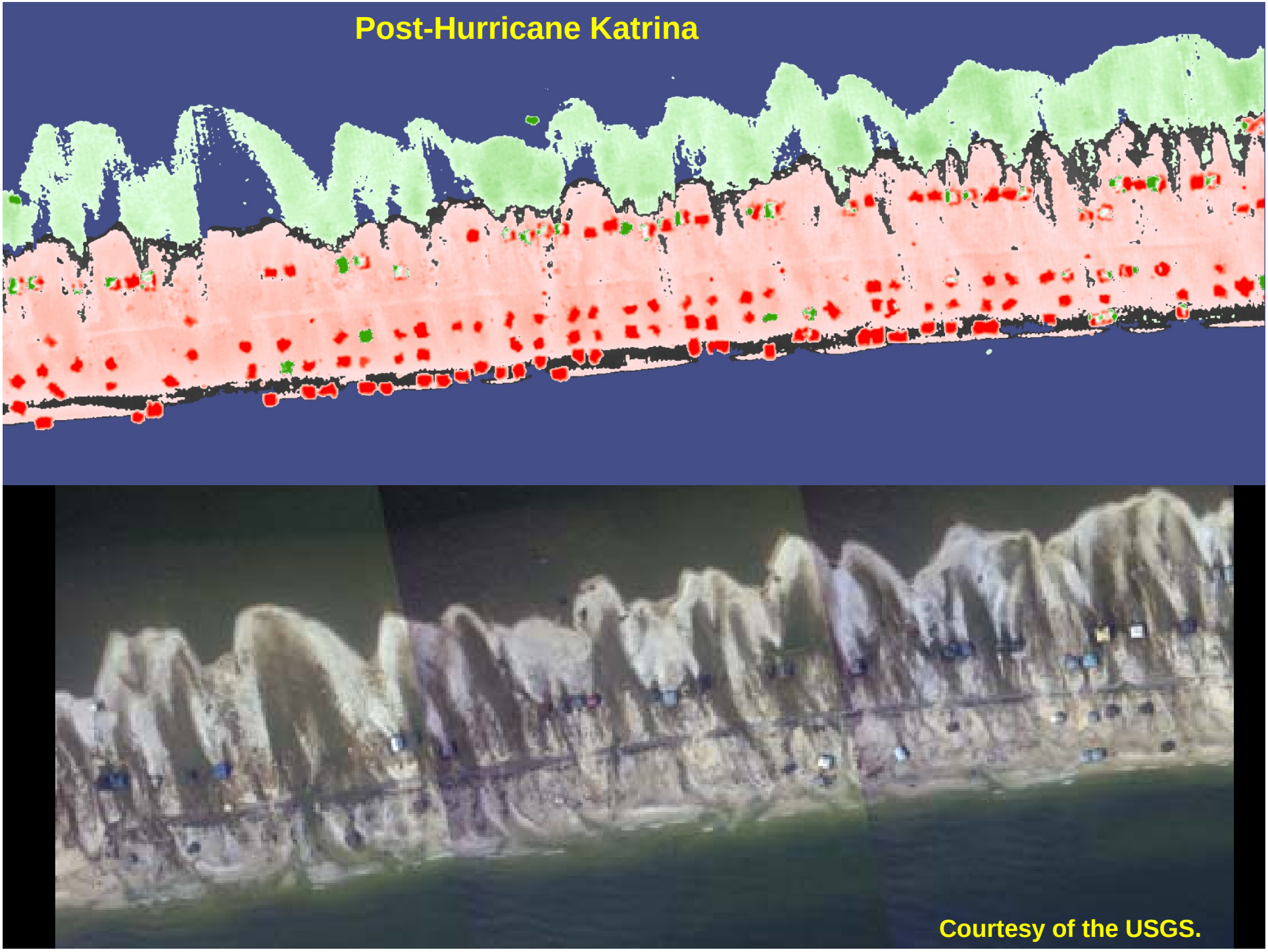



Dauphin Island, Al - Pre-Hurricane Ivan
Elevation
0.2 2 4 6 8 10 12 14
Meters
Houses on a barrier island.
Courtesy of the USGS.


Post-Hurricane Ivan
Courtesy of the USGS.


Post-Hurricane Katrina
Courtesy of the USGS.


Post-Hurricane Katrina
Courtesy of the USGS.


Post-Hurricane Katrina
Courtesy of the USGS.

My Background – Reide Corbett

- **B.S., M.S., Ph.D. Florida State Univ., Post Doc Tulane Univ.**
- **Joint-appointed Associate Professor in Geological Sciences and Institute for Coastal Science & Policy at ECU.**
- **Interested in sediment and nutrient dynamics. Natural and human-impacts of the coastal system.**

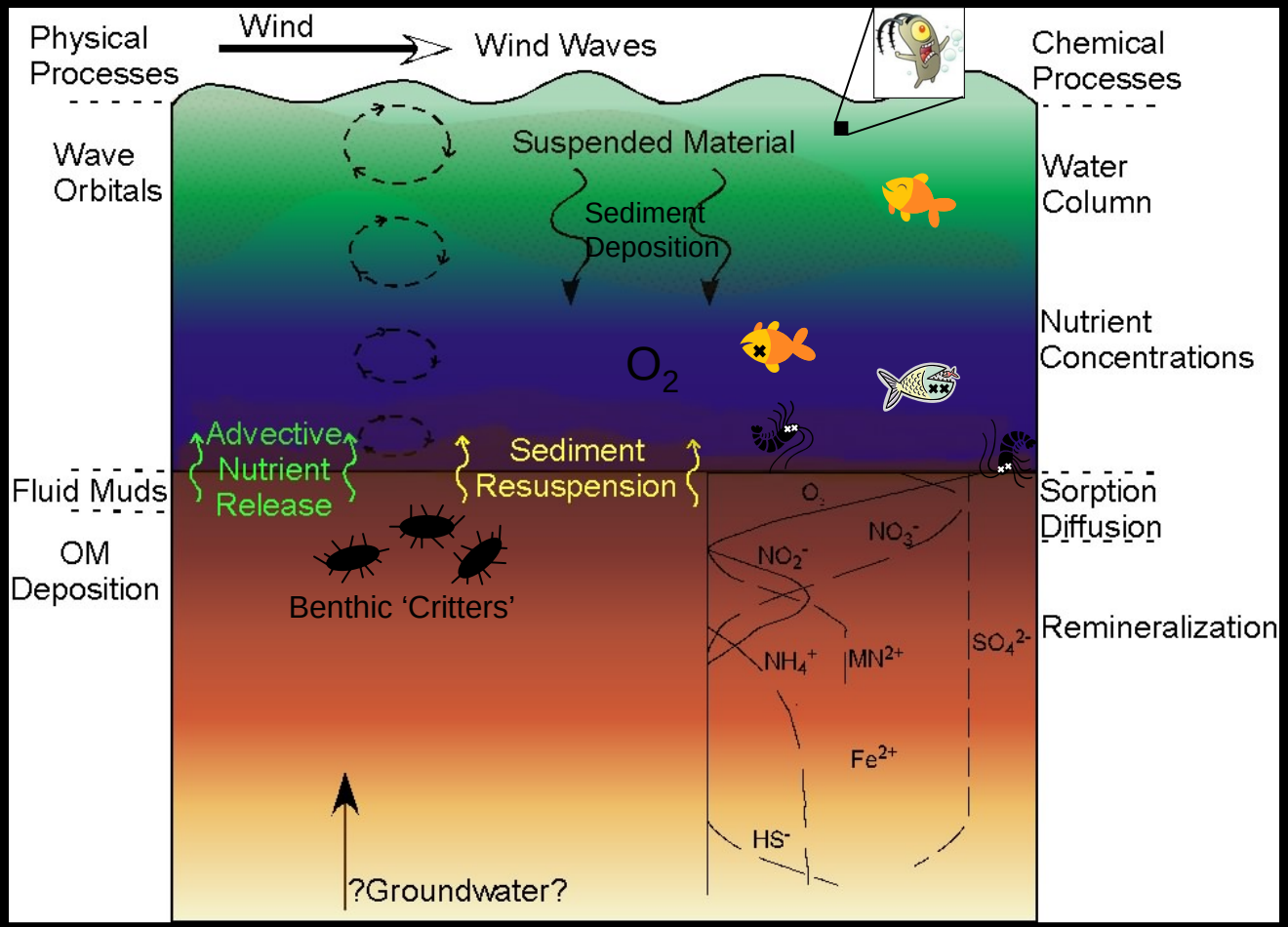


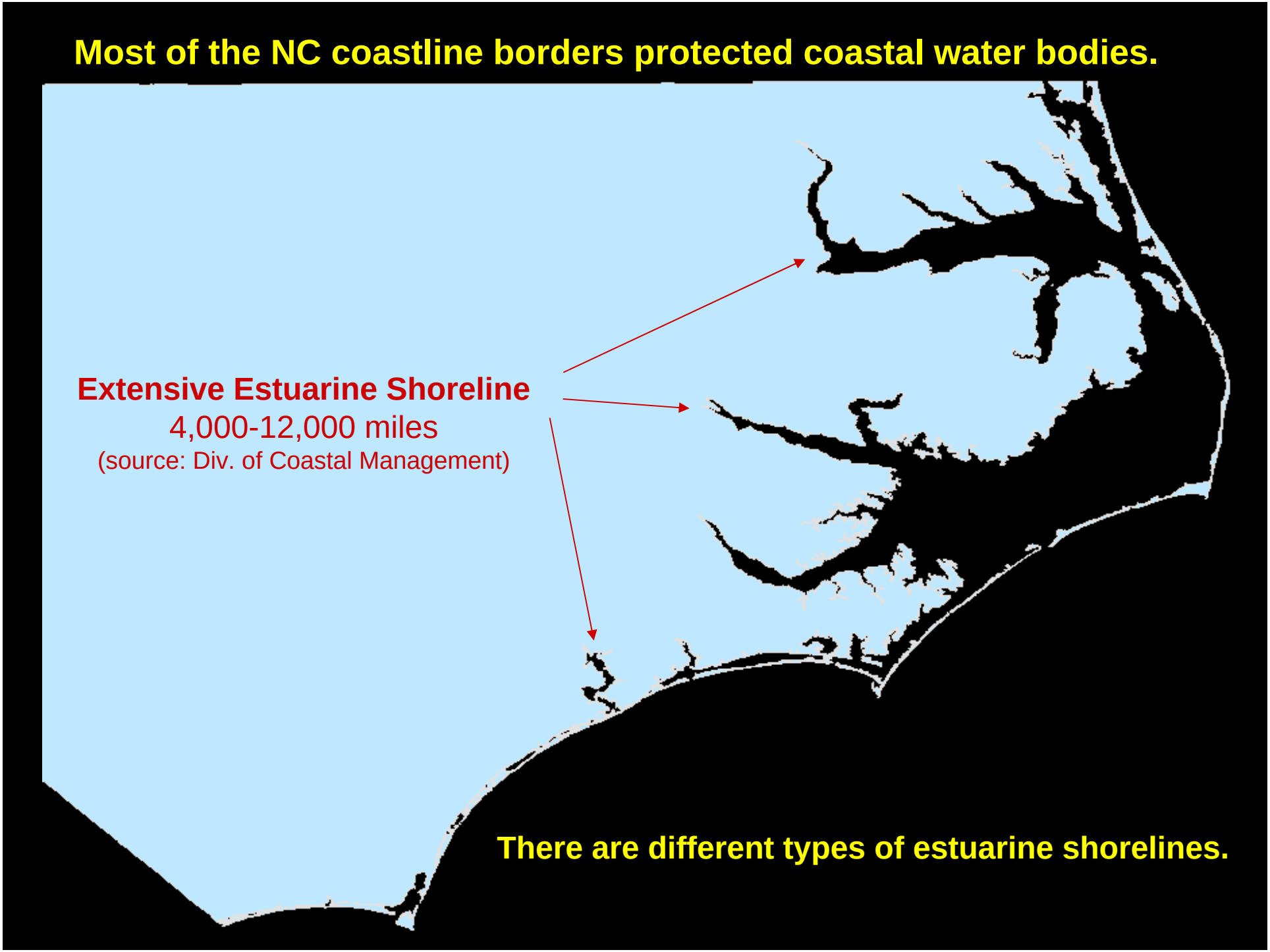

Photo by Don Bowers

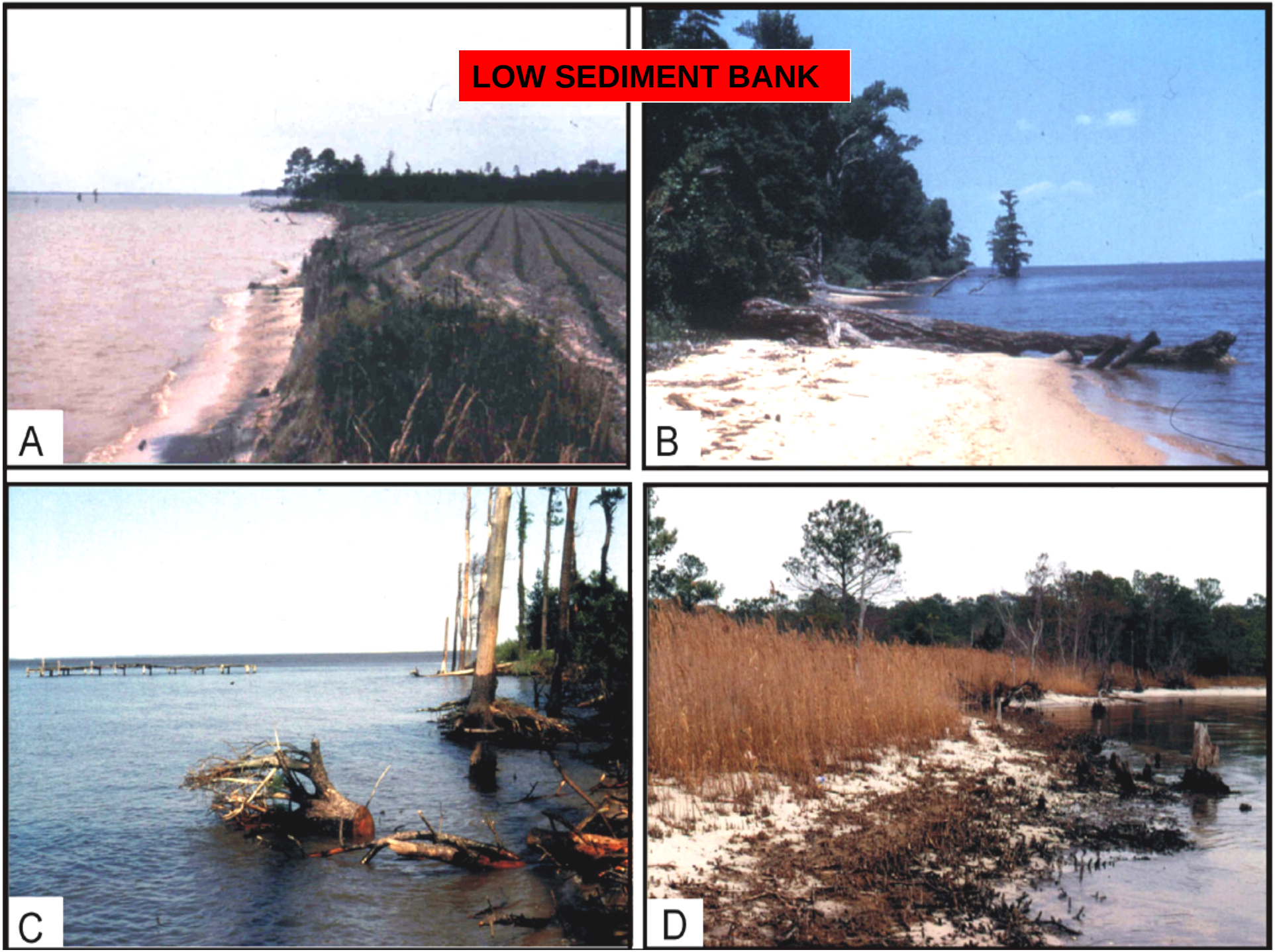

Photo by Don Bowers

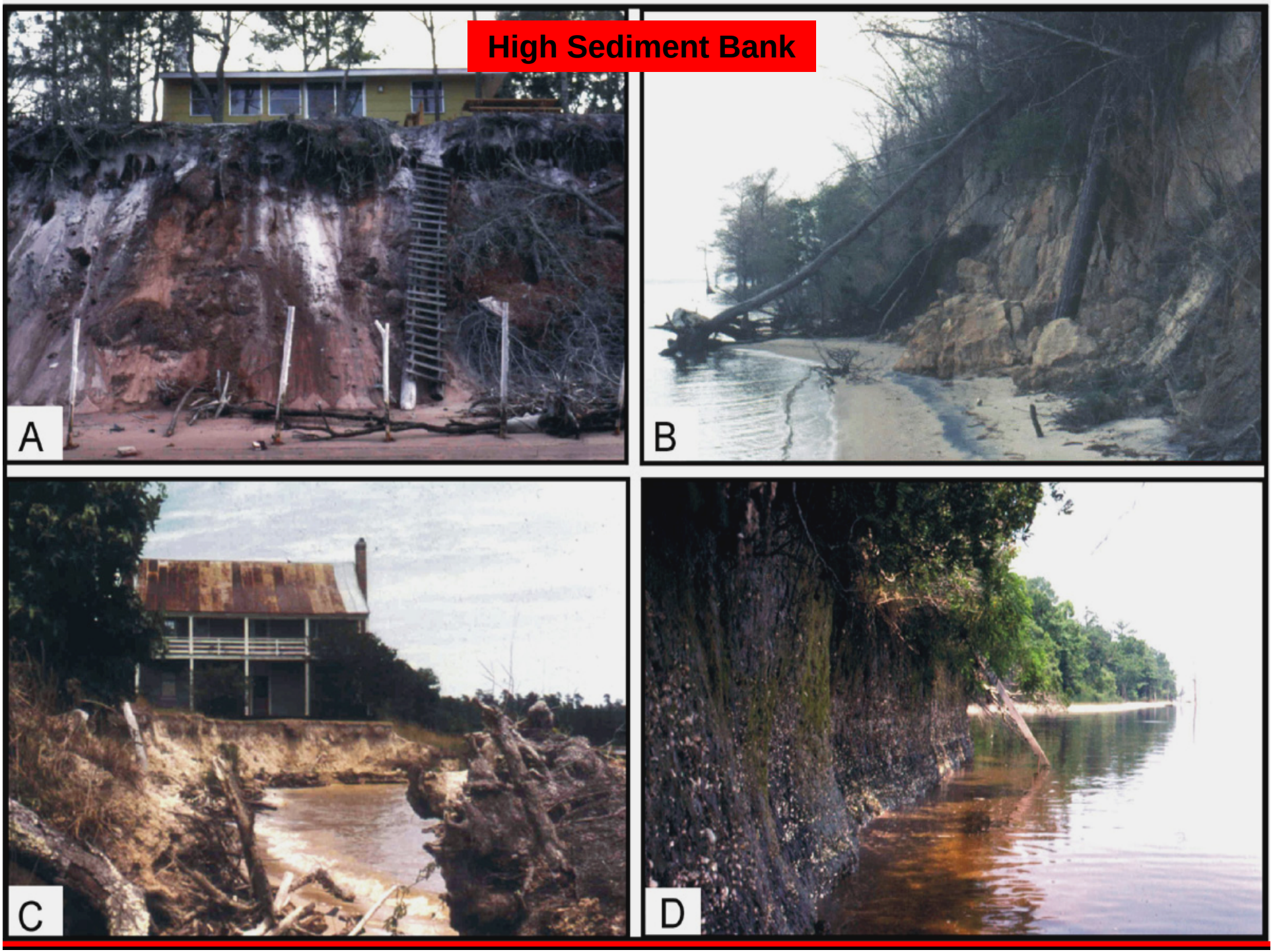
Photo by Don Bowers

Photo by Don Bowers

Most of the NC coastline borders protected coastal water bodies.




LOW SEDIMENT BANK
A
B
C
D


High Sediment Bank
A
B
C
D

SWAMP FOREST SHORELINE

PLATFORM MARSH

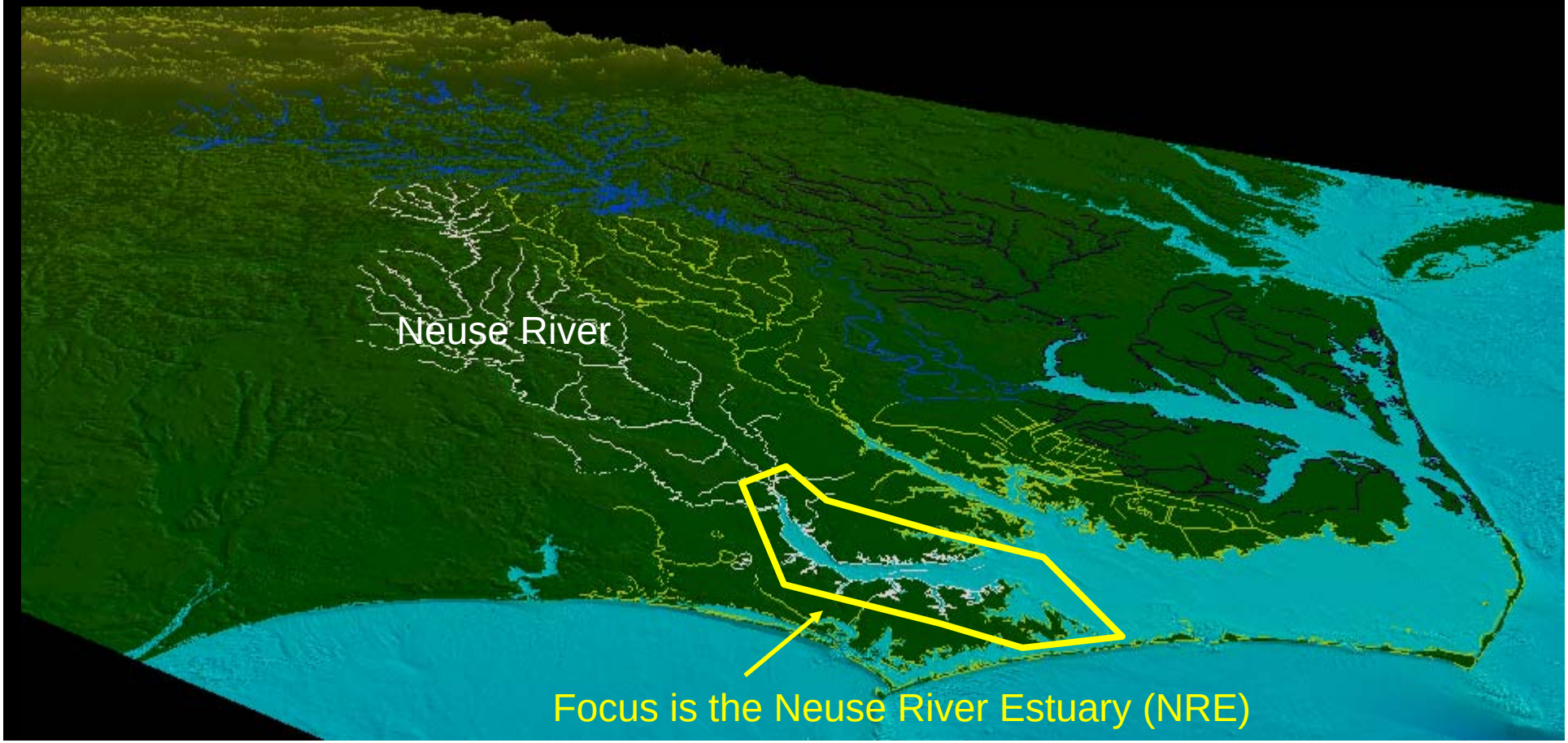
Bulk headed Shoreline – more common than you think!

FILLING & HARDENING
WETLAND SHORELINES

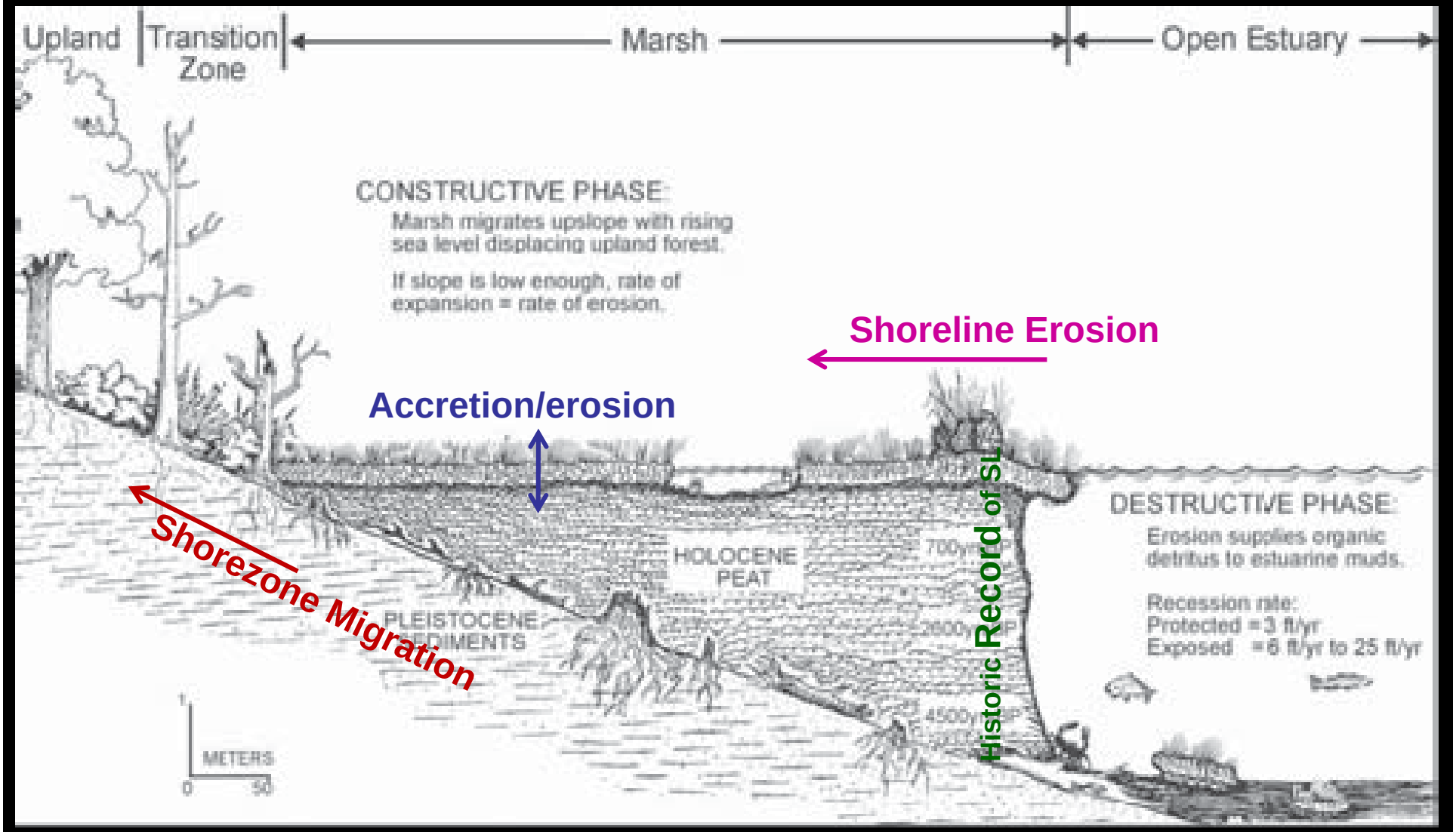
NO WETLANDS—
NO SEAFOOD!!!!!

So, what are we doing…

1) How has sea-level risen over the last century?
2) How, where, and why has the shoreline position changed?
3) How does land-cover vary in the NRE region and has the shorezone changed (e.g., wetland loss) over this period.



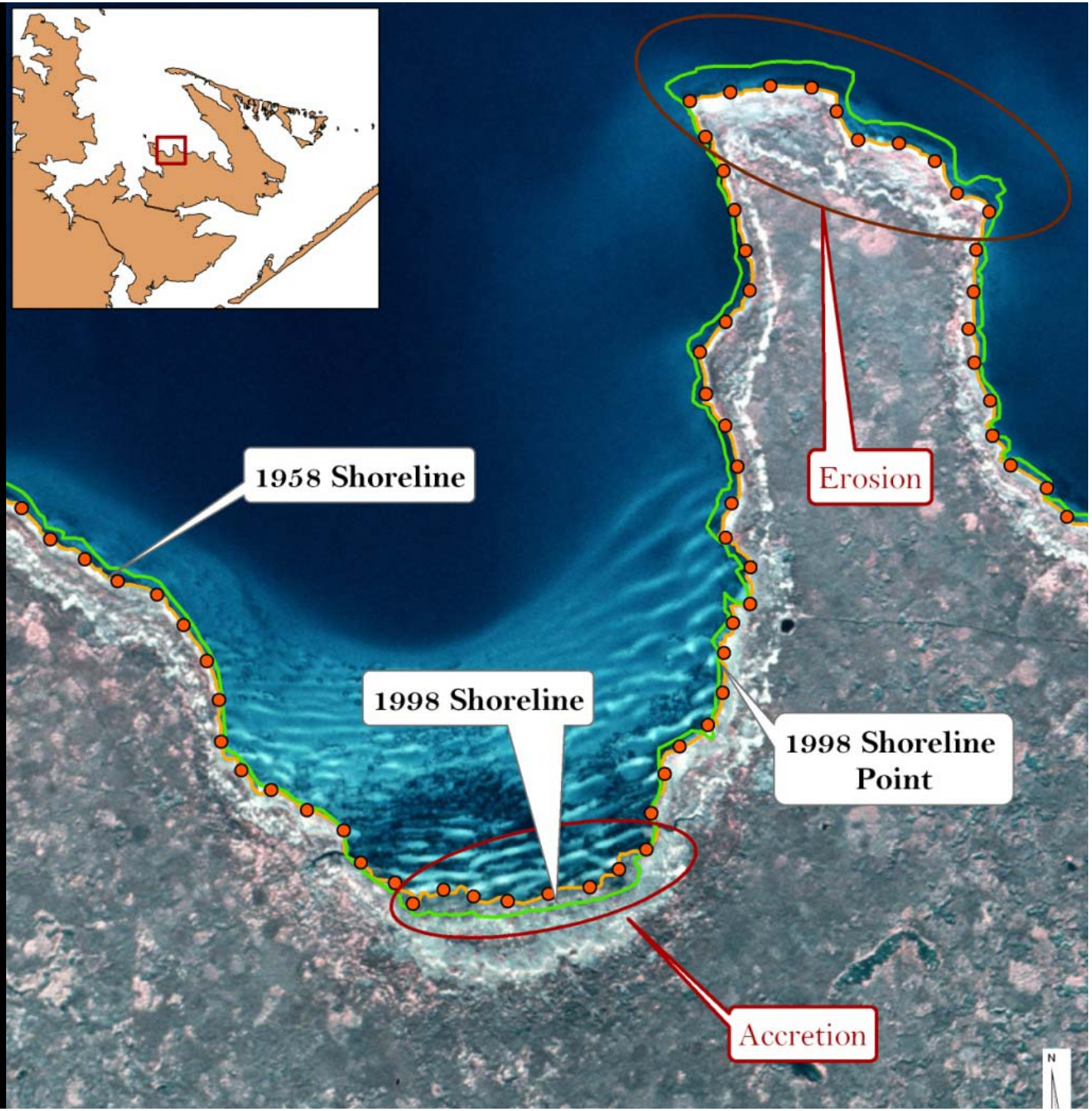
Influence of Sea Level Rise in Coastal NC

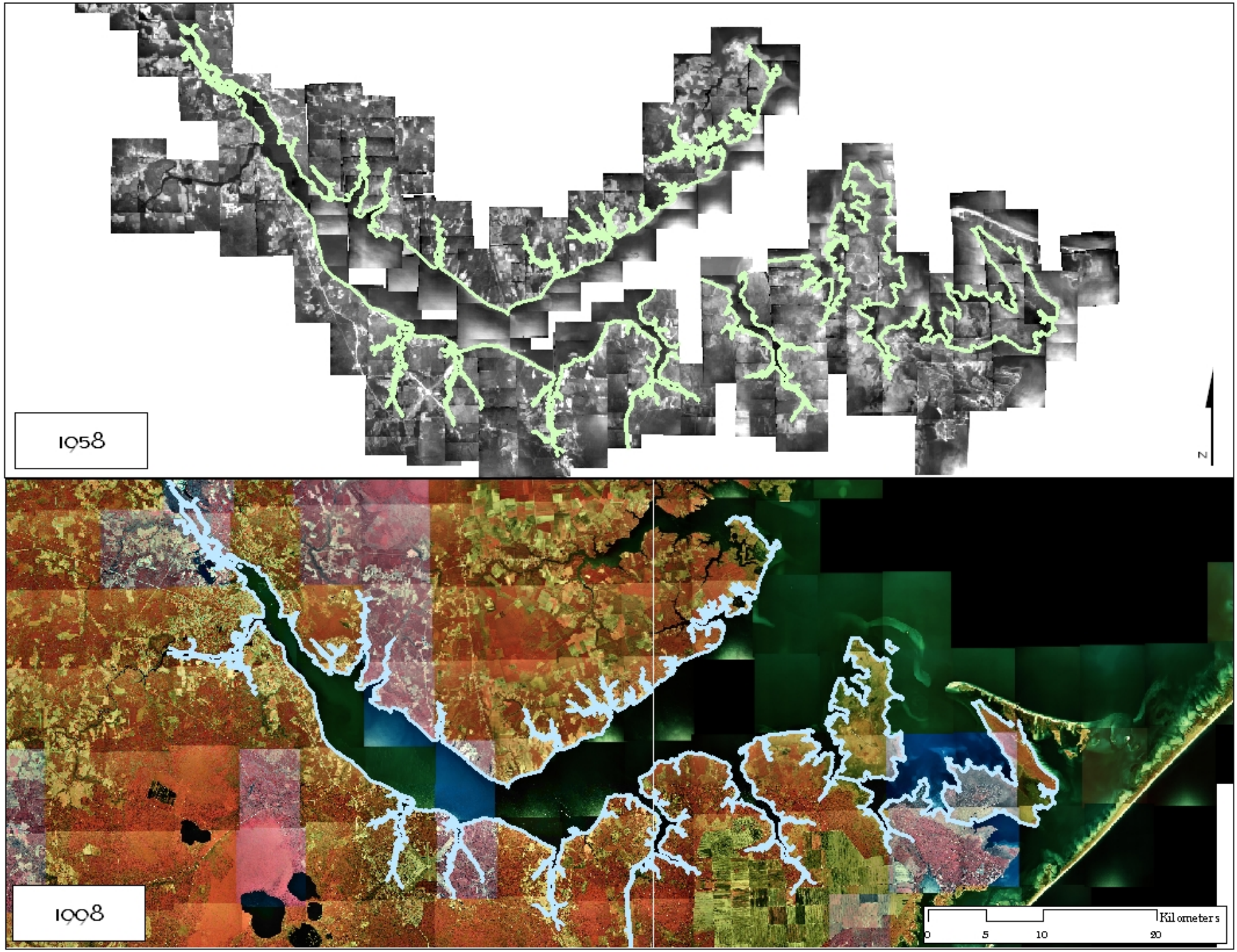


Ecosystem-functioning and Human-resource Implications

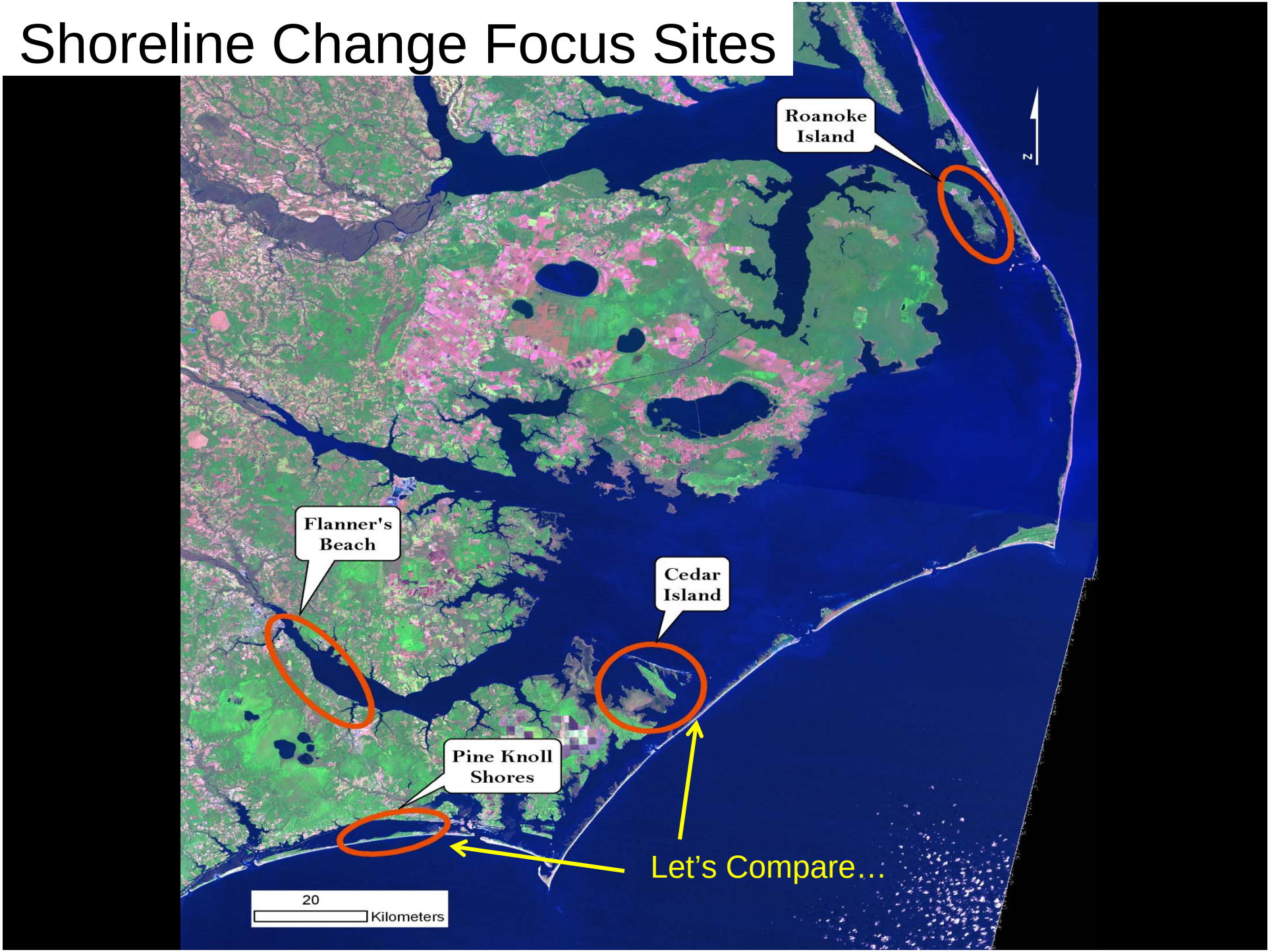
- **Loss of wetland habitat.**
  - Natural filter improving water quality
  - Critical fisheries habitat
  - Storm flooding protection
- **Loss of expensive coastal property.**
- **Damage and Destruction to coastal infrastructure.**

Quantifying Shoreline Change

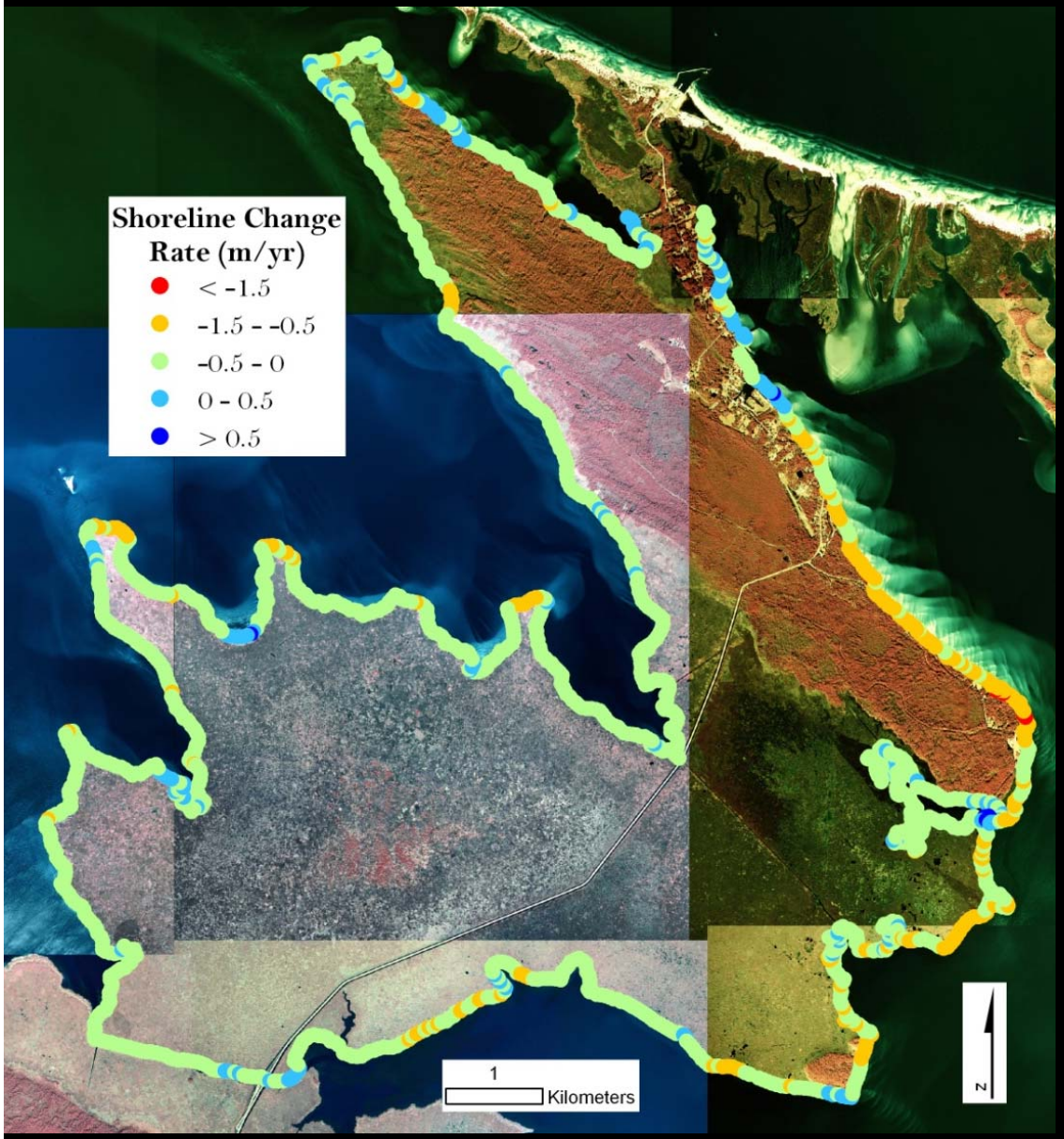



1058
N
1998
Kilometers
0
5
10
20

Shoreline Change Focus Sites



Cedar Island

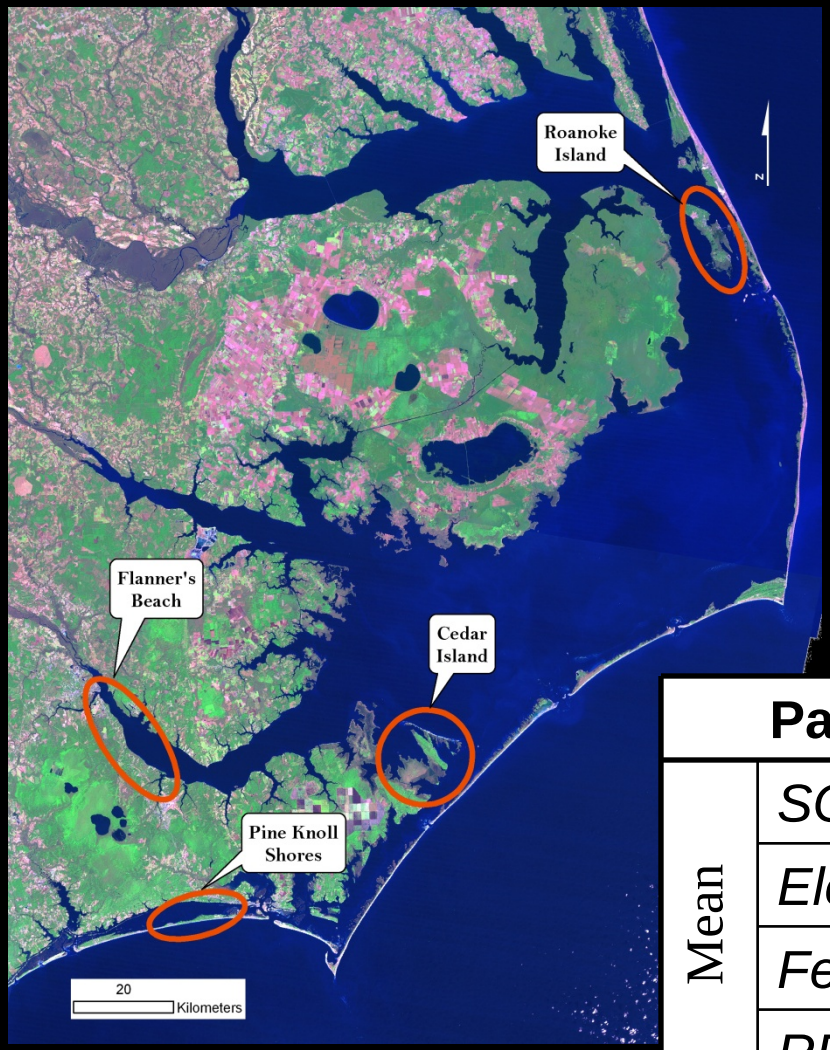


- Mean SCR of -0.24 m yr^{-1} with 88% eroding.
- Mean fetch values ranged from 0 to 9.3 km, with the average fetch of the study area being 1.5 km
- Dominant land cover type is estuarine emergent wetland (79%), with scrub/shrub and evergreen forest being the second and third most abundant. Together, these three land cover types compose 92% of the shoreline analyzed.

Pine Knoll Shores

- Mean SCR of the area was 0 m yr^{-1} with a range from –0.9 to 1.8 m yr^{-1}
- Mean values ranged from 0 to 2.9 m and the average elevation of the shoreline was 0.7 m
- Mean fetch of 2 km
- Estuarine emergent wetland is most abundant land cover, composing 43% of the shoreline

Site Summary

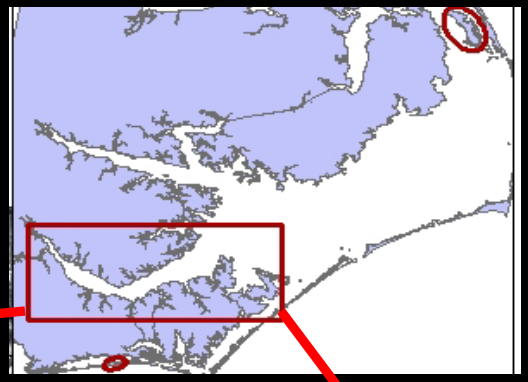


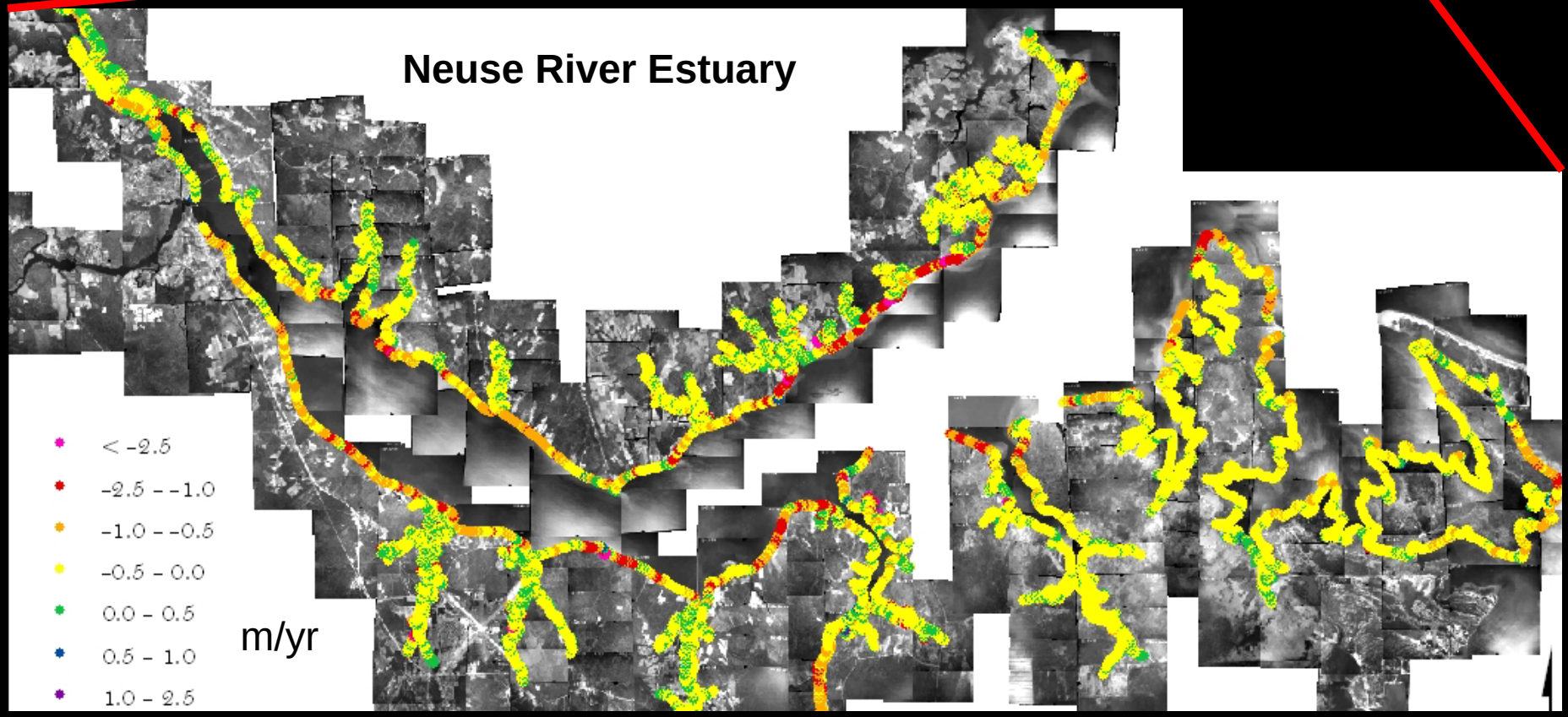
- **Significant variation in SCR throughout the APES**
- **Relationship between elevation/fetch and SCR (erosion), but not a simple linear function.**

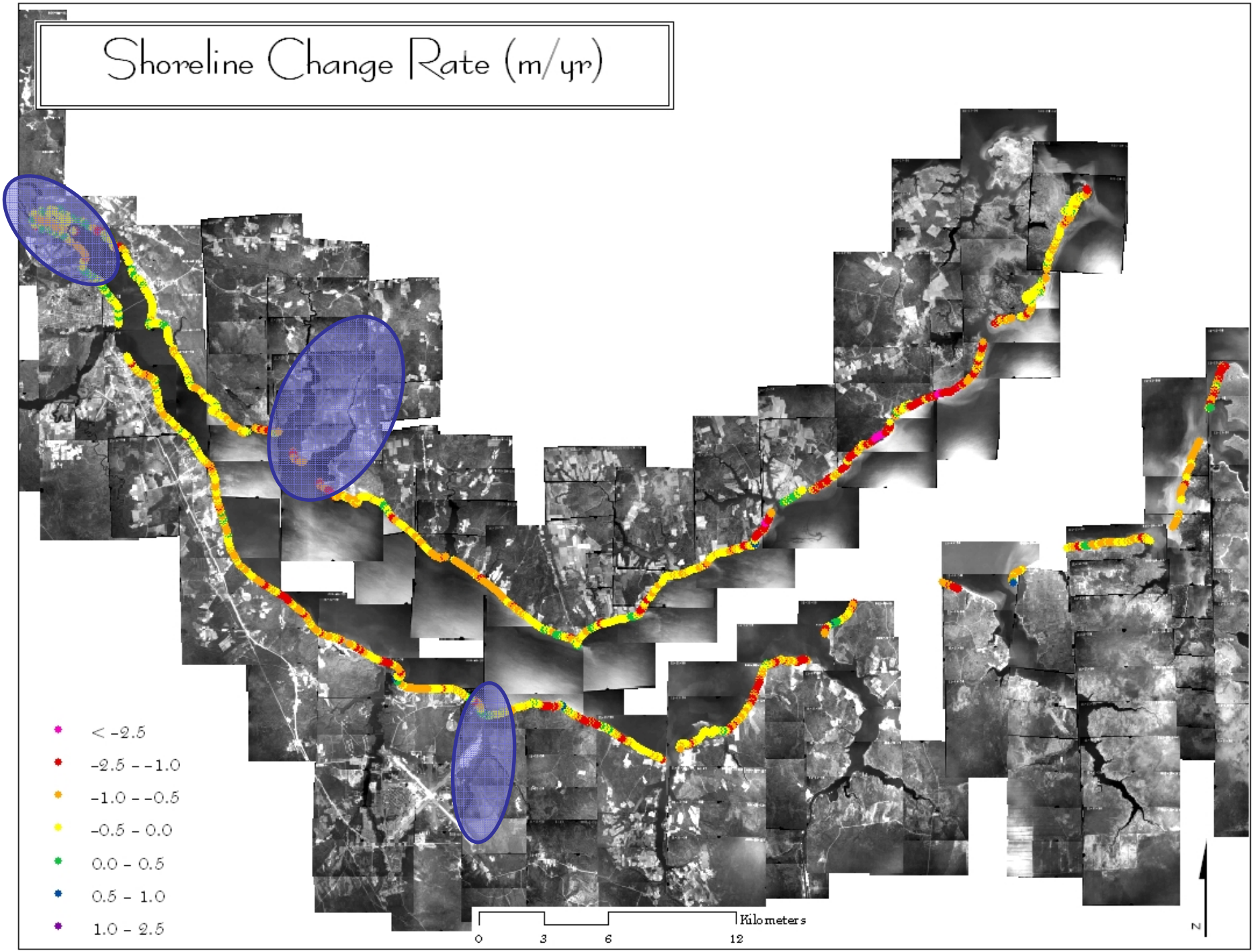
Parameter		FB	RI	CI	PKS
Mean	*SCR (m/yr)*	-0.57	-0.36	-0.24	0.00
	Elevation (m)	1.8	1.3	0.6	0.7
	Fetch (km)	3.0	N/A	1.5	2.0
	REI	273	N/A	318	66

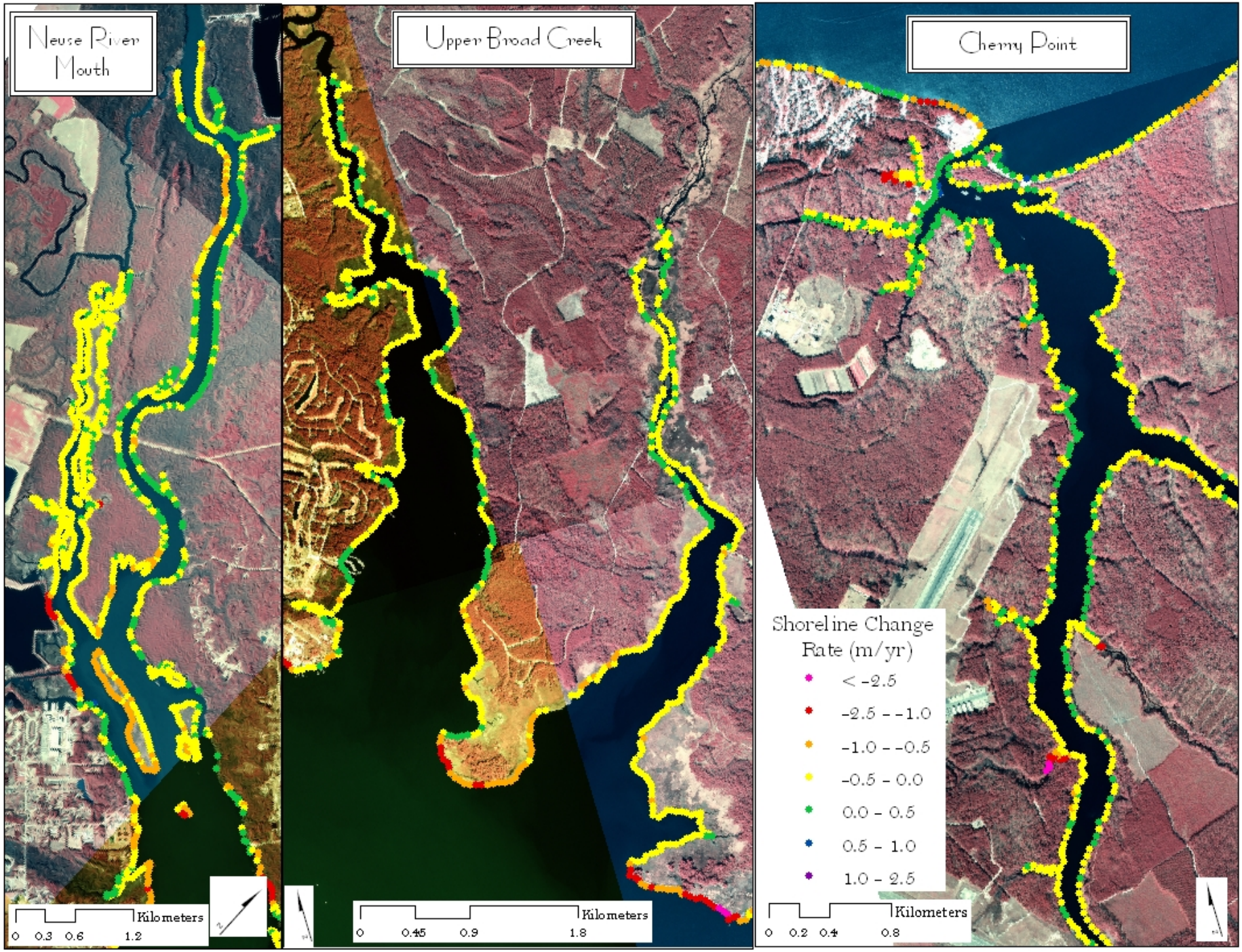
Estuarine Shoreline Erosion Rates

- **Erosion rates show great variability; however, they are large (>6 ft/yr) in some locations.**
- **Prediction cannot easily be accomplished as many factors (e.g., fetch, hardening) are important.**






Shoreline Change Rate (m/yr)
< -2.5
-2.5 - -1.0
-1.0 - -0.5
-0.5 - 0.0
0.0 - 0.5
0.5 - 1.0
1.0 - 2.5
Kilometers
0
3
6
12
N


Neuse River Mouth
Upper Broad Creek
Cherry Point
Shoreline Change Rate (m/yr)
< -2.5
-2.5 - -1.0
-1.0 - -0.5
-0.5 - 0.0
0.0 - 0.5
0.5 - 1.0
1.0 - 2.5
Kilometers
0 0.3 0.6 1.2
Kilometers
0 0.45 0.9 1.8
Kilometers
0 0.2 0.4 0.8

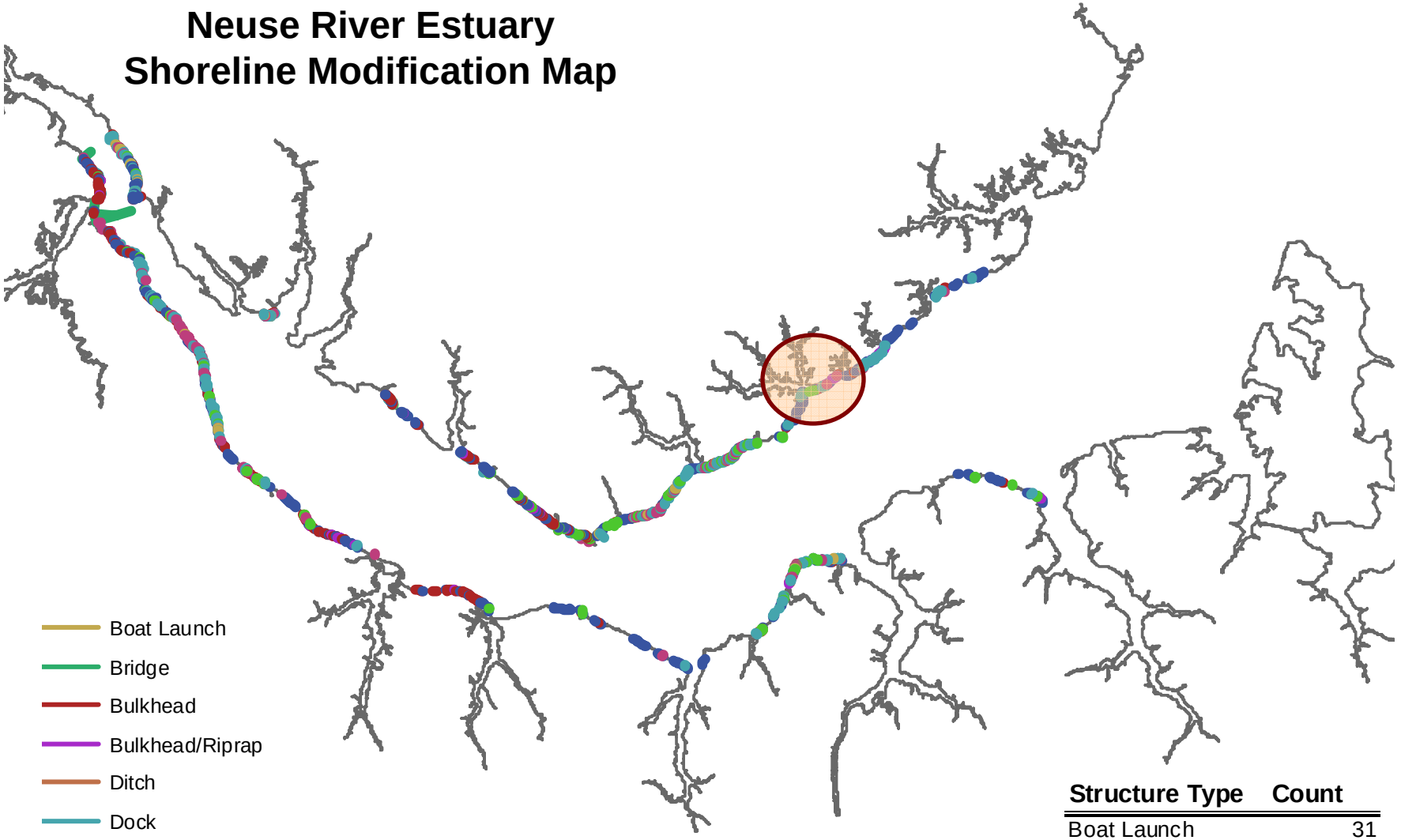
Shoreline Modification

+

+

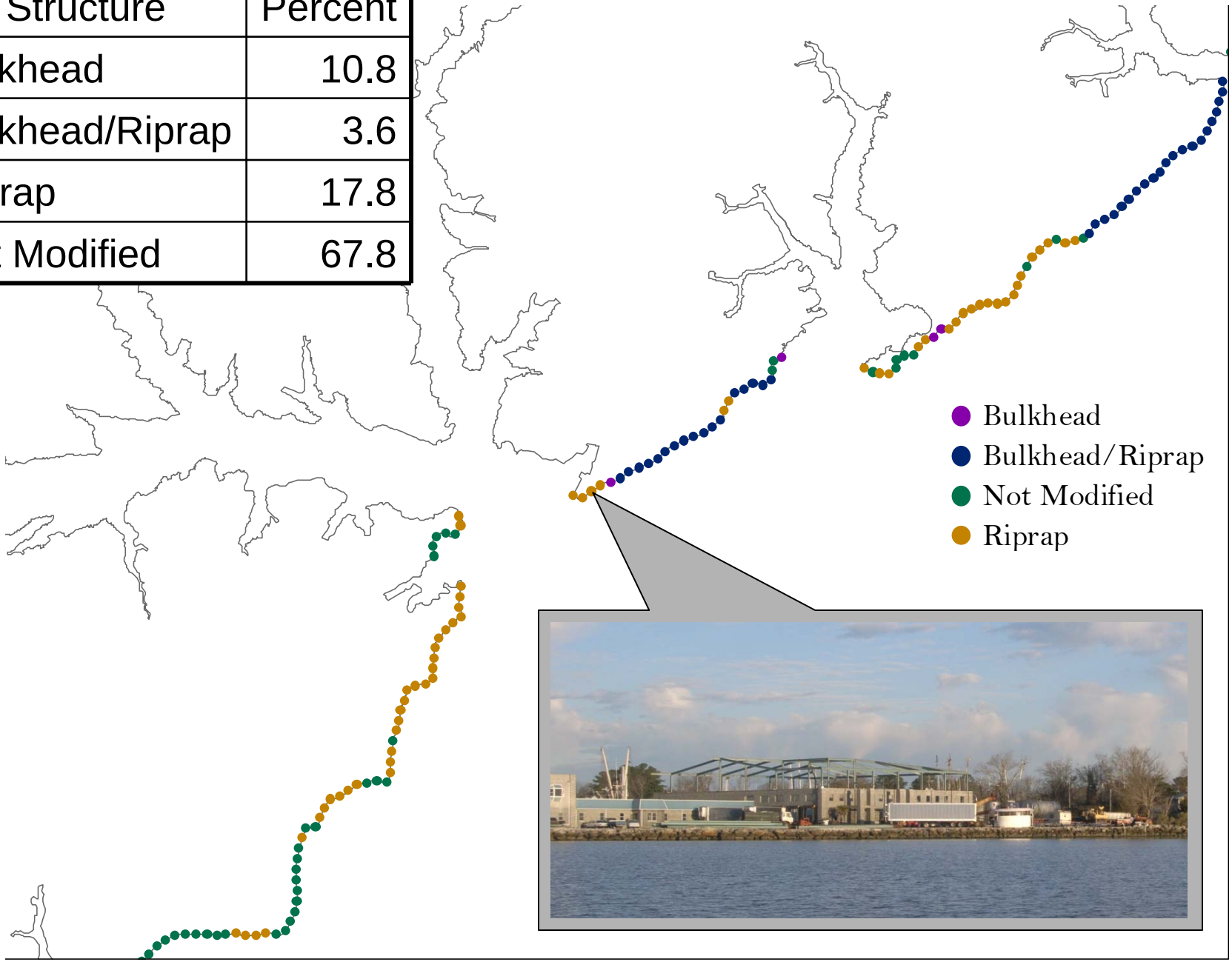
- Used ArcPad software, laptops, in conjunction with GPS units
- Structures were heads-up digitized as the boat motored perpendicular to shore
- GPS camera documente modified structures

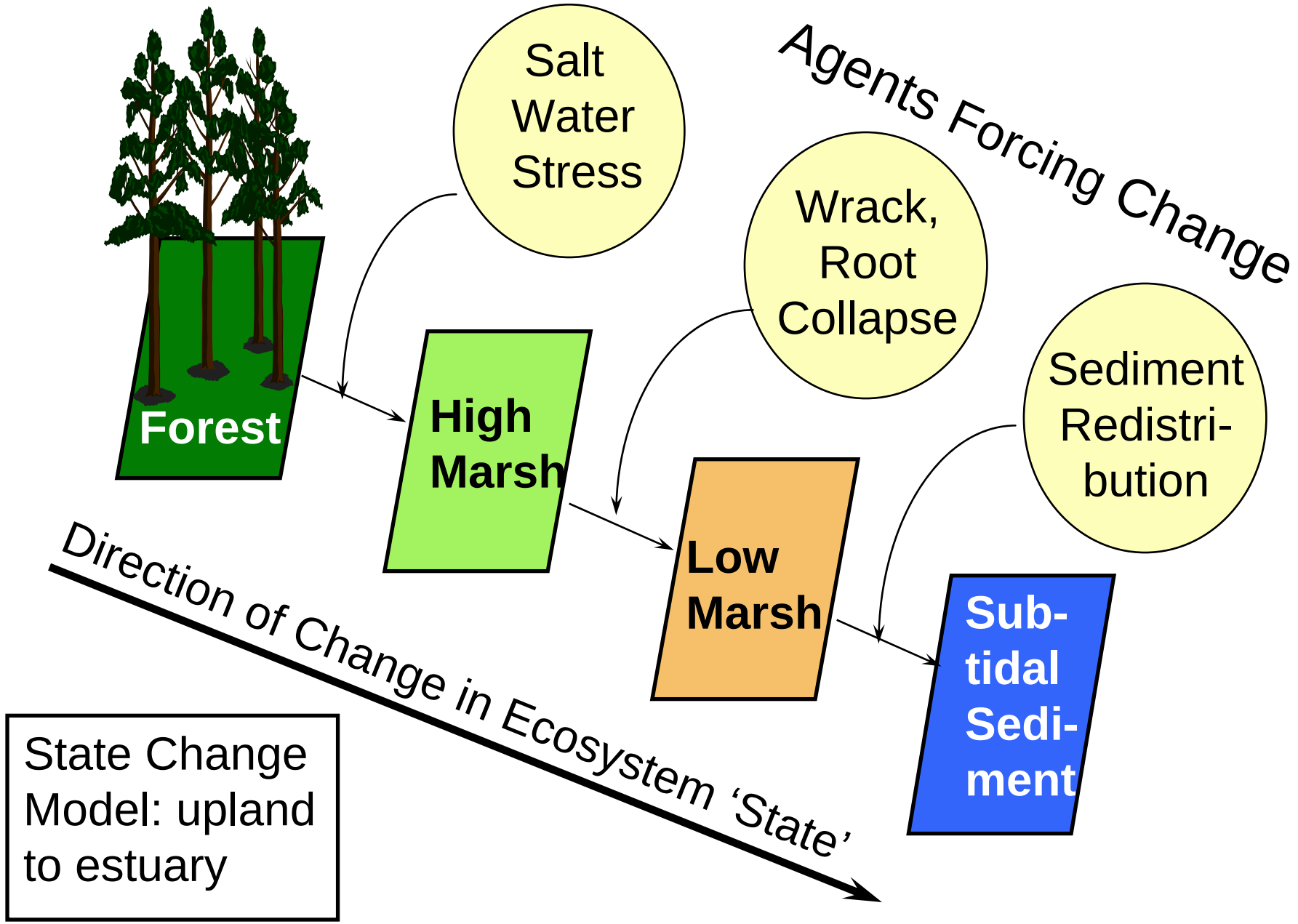
Neuse River Estuary
Shoreline Modification Map



Structure Type	Count
Boat Launch	31
Bridge	16
Ditch	3
Dock	307
Groin	170
Ruin	118
Structure	2

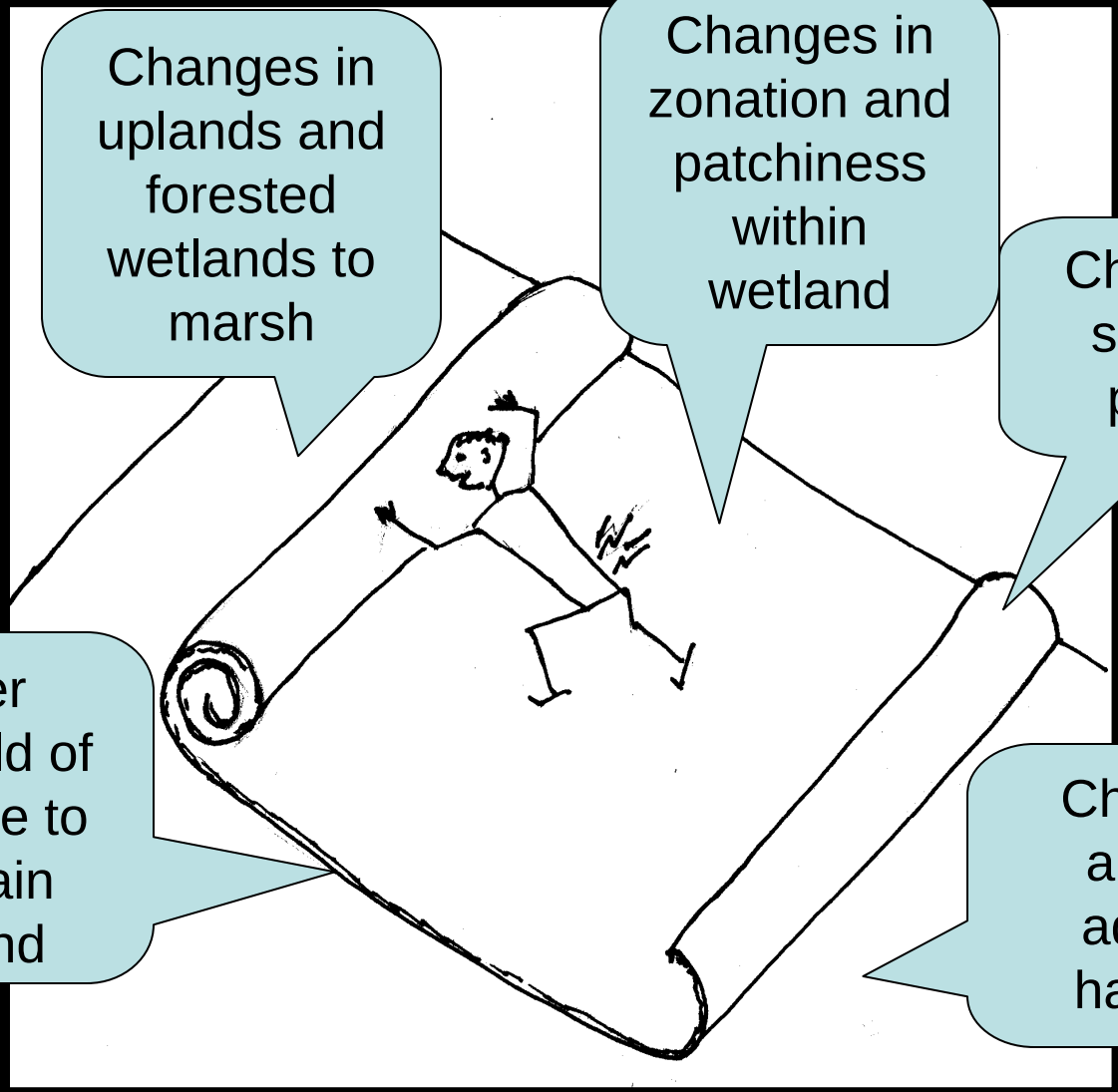
Structure	Percent
Bulkhead	10.8
Bulkhead/Riprap	3.6
Riprap	17.8
Not Modified	67.8





Information development and prediction

The Carpet Model



Changes in uplands and forested wetlands to marsh

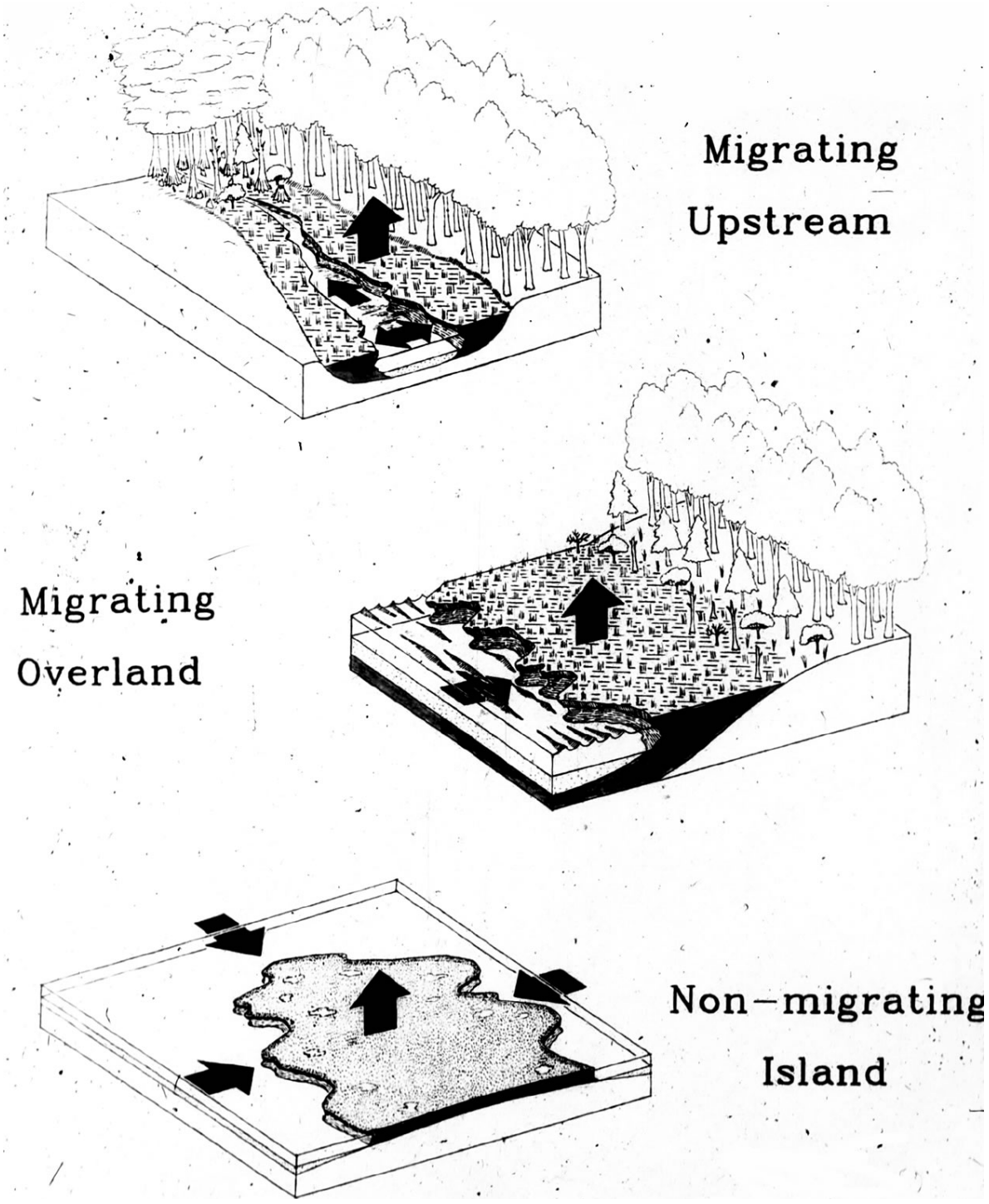
Changes in zonation and patchiness within wetland

Changes in shoreline position

Upper threshold of SLR rate to maintain wetland

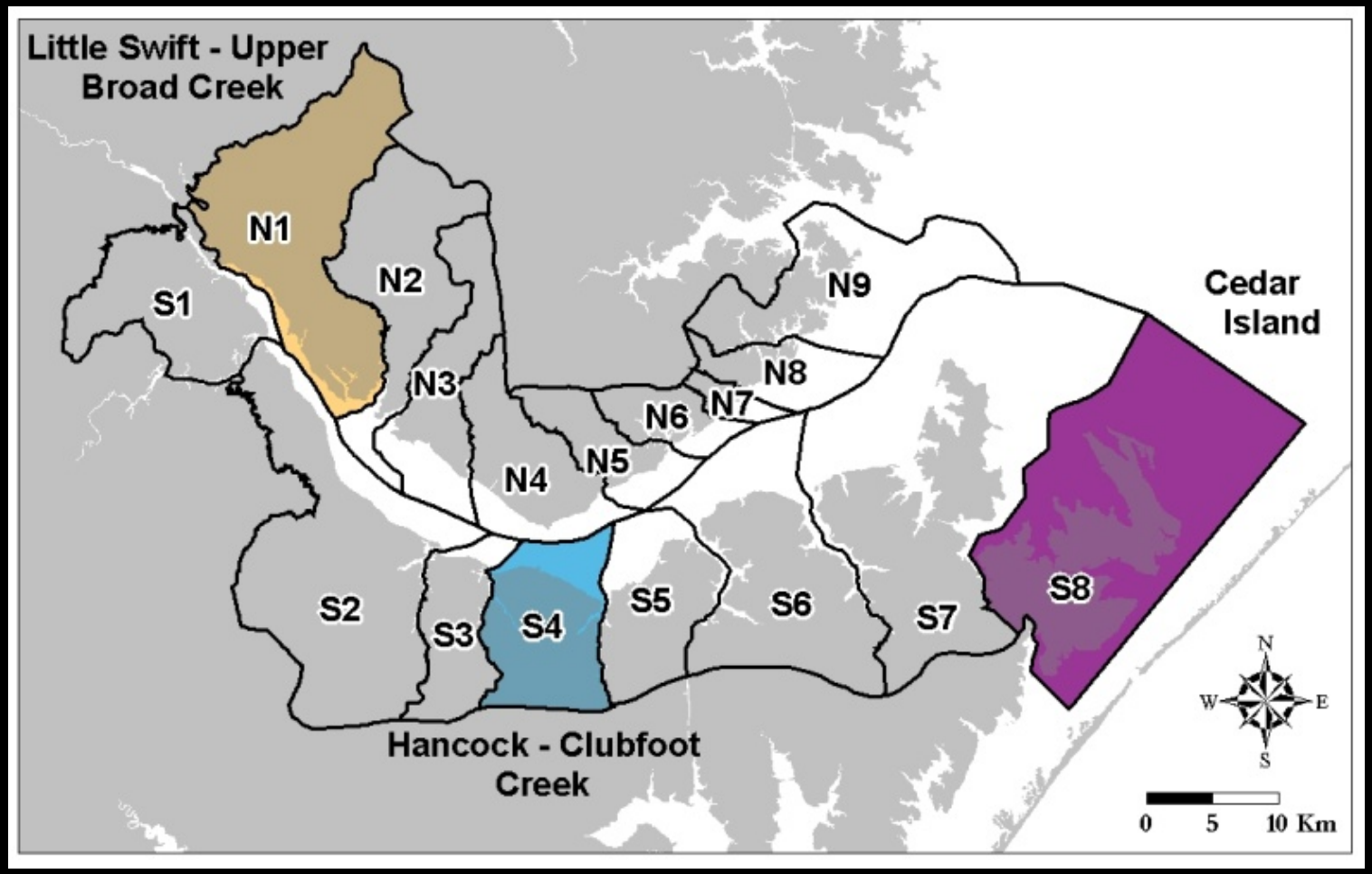
Changes among aquatic habitats

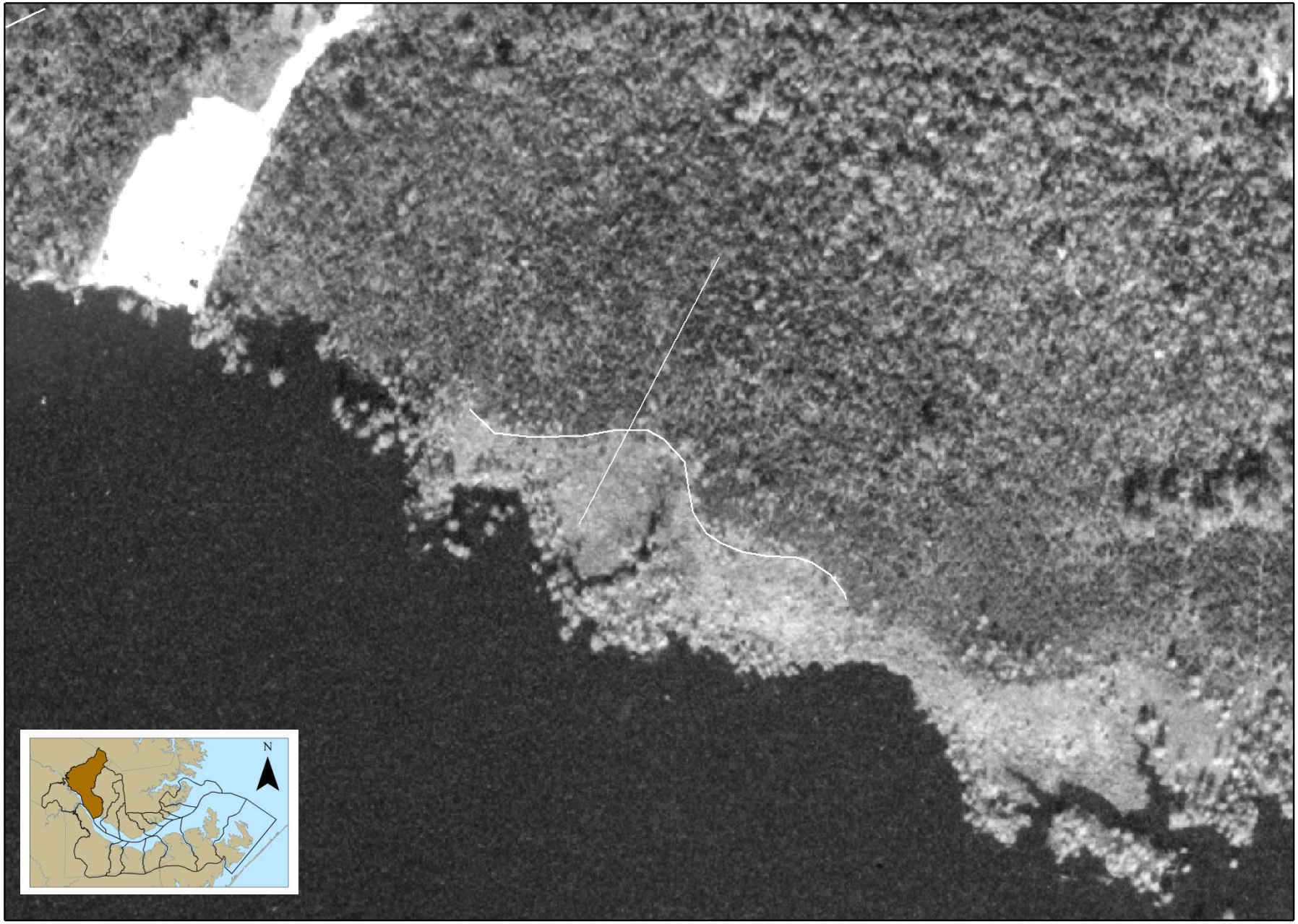
Geomorphology – migrating to stalling


Migrating
Upstream
Migrating
Overland
Non–migrating
Island

Shorezone Variation

- **Investigating vegetation boundary changes between the 1958 and 1998 at select study sites.**





Neuse River 1958

Neuse River 1998

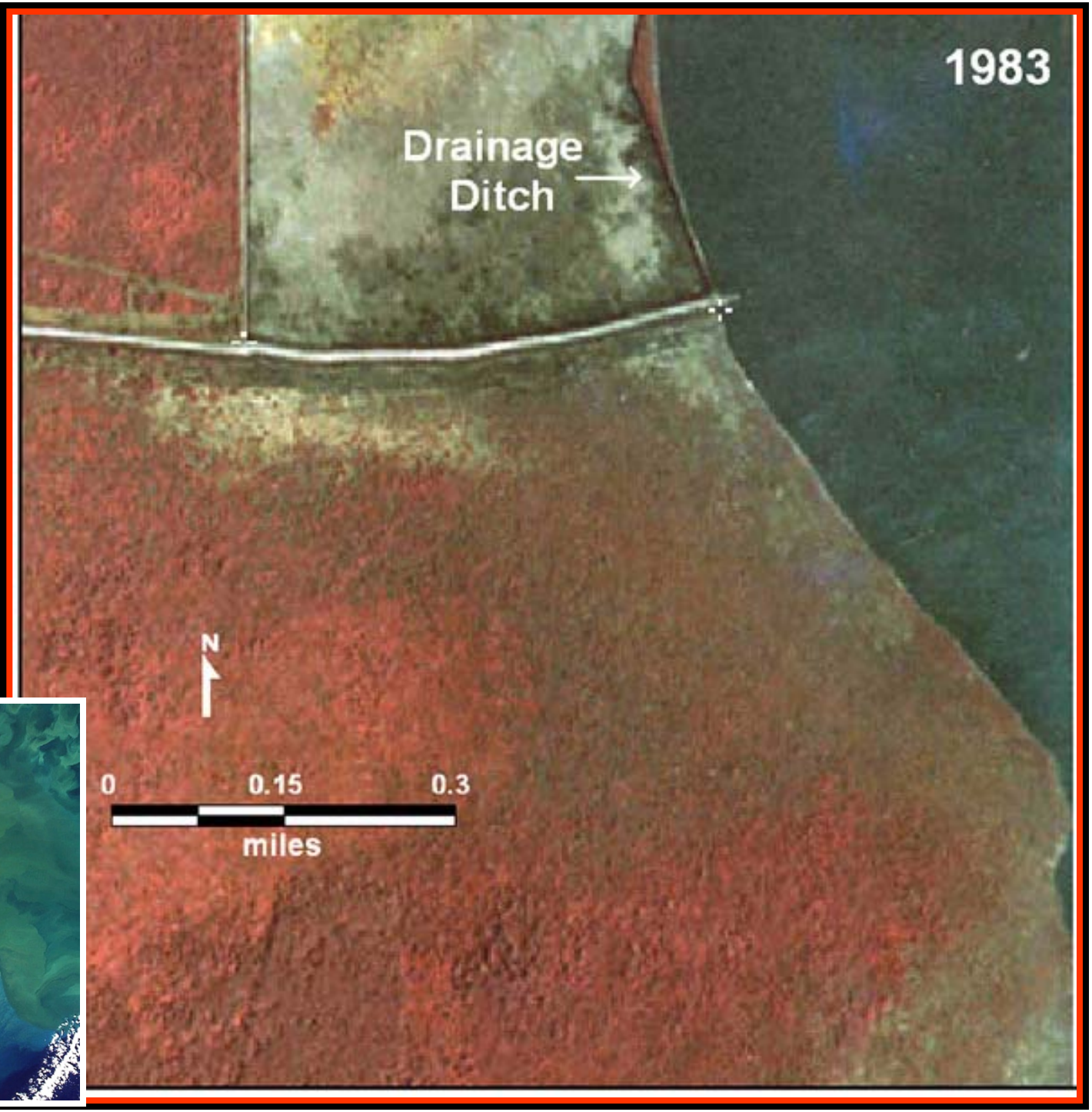

Neuse River 2008


Lola Road
1958
0
50
100
200
300
400
Meters


Lola Road
1998
0
50
100
200
300
400
Meters


Lola Road
2008

Stalling Transition



When thinking about adaptations…

1) Preserve coastal NC in a functional state similar or better than today.

2) Protect resources not at expense of the health and functioning of the natural environment (which our coastal economy is heavily dependent upon).

General Conclusions

- **The NC coast has been and will increasingly be under the threat of climate change.**
- **There are a diversity of potential consequences of climate change, and these will have impacts on the coastal NC economic engine.**
- **You can learn more about NC coastal hazards at our web site (see hand out).**
- **Estuarine shoreline erosion is an important hazard affecting NC.**

Recommendations

- Determine what existing infrastructure is at risk and establish the best methods for adaptation. (DOT, counties, towns, home owners)
- Plan carefully about the placement and character of new infrastructure in the coastal zone.
- Determine in advance how to respond once infrastructure is removed by a disaster or is at the end of its engineered life.
  (Are we going to keep replacing roads and bridges?)
- Create policy that ensures planning, preparation and action.
- DENR, DOT, etc. should prioritize dealing with coastal hazard risks and must be funded at an appropriate level to do so.

Specific Estuarine Erosion Recommendations

- **Estuarine shorelines must be more closely managed to protect sensitive habitat areas and aid property owners.**
- **Need baseline information on the state of the estuarine shoreline, habitats, and structures and monitor change.**
- **Develop an explicit policy on the management of the estuarine shoreline. (site dependent hardening)**
- **Create a shoreline hardening assessment across the state to guide decision-making by property owners and managers.**

Coasts in Crisis

Steve Culver and David Mallinson will speak at the next Climate Commission meeting.