2019 North Carolina Coastal Conference

November 19-20, 2019

Wilmington, NC

#NCCoastConf

NC Sentinel Site Cooperative

Tuesday, Nov 19: NCSSC Research Updates session

Highlighting research updates from the NCSSC over the past five years: Learn about sea level rise impacts to marshes, dunes and beaches, people, and water quality.

For more information, contact NCSSC Coordinator Sarah Spiegler: sespiegl@ncsu.edu

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

SENTINEL SITE COOPERATIVE NORTH CAROLINA

Sea Grant North Carolina

North Carolina Sentinel Site Cooperative

Research Updates

Sarah Spiegler, NC Sentinel Site Cooperative Coordinator

NC Coastal Conference, November 19, 2019

NOAA Sentinel Site Program

- **Place-based and issue-driven approach**

Current issues: sea level rise (SLR), coastal inundation, flooding, coastal resilience

- **Cooperatives established in 2012**

NC Sentinel Site Cooperative (NCSSC) Goals

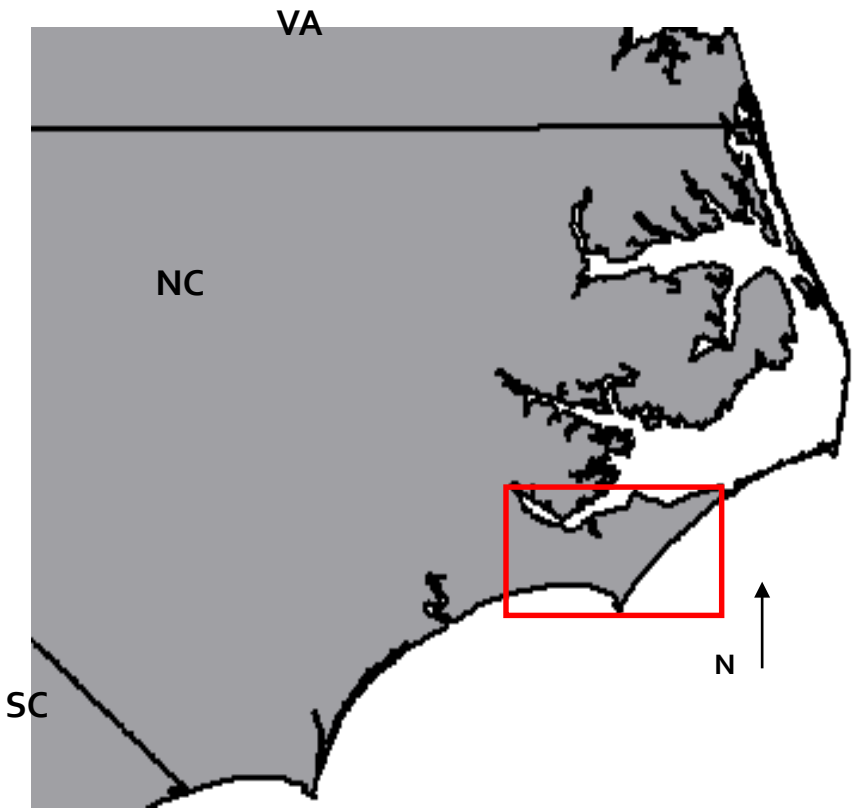
1) Conduct research and monitoring

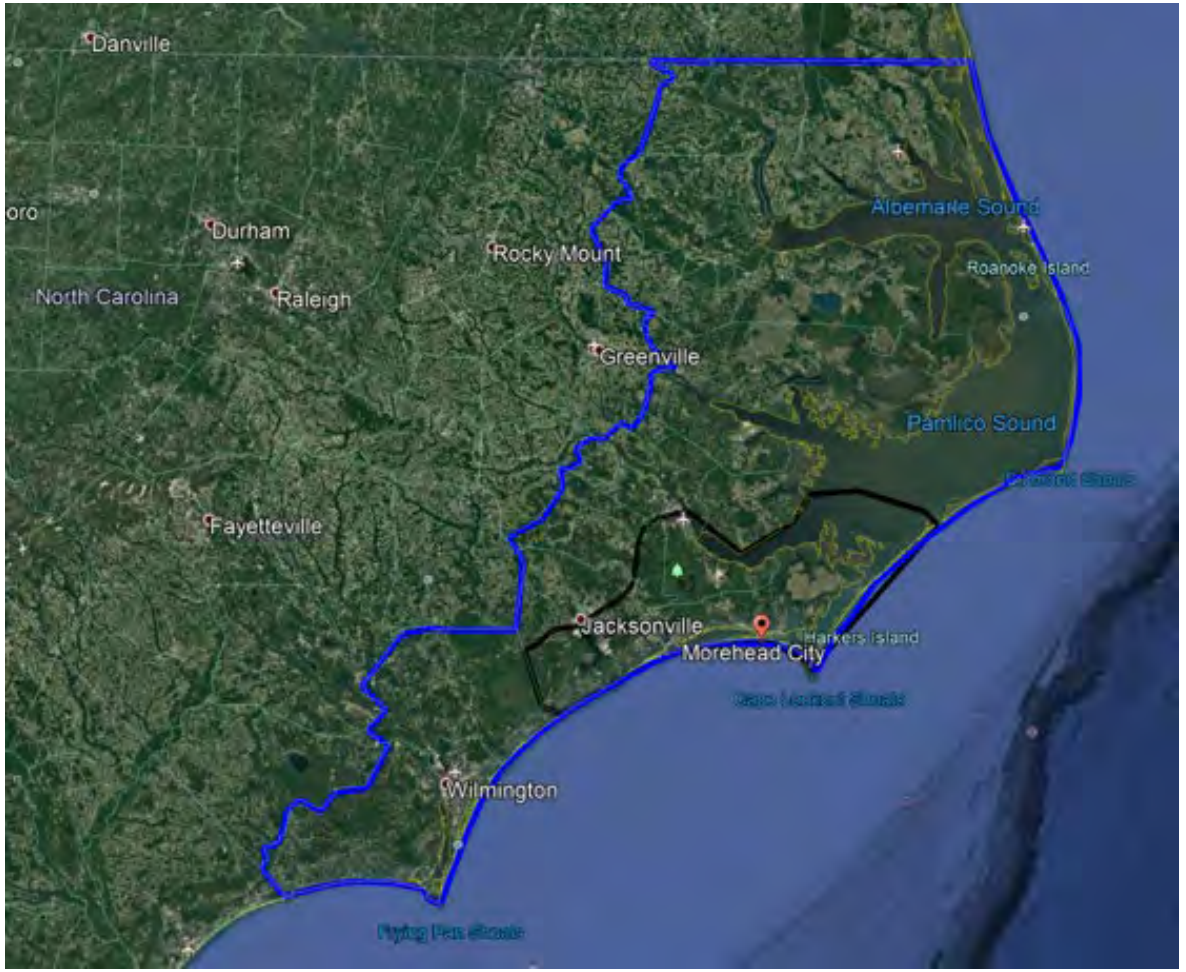
2) Integrate science into decision-making

3) Inform coastal residents

Mission: Work collaboratively and leverage resources to provide research, monitoring, and information for addressing coastal resiliency to flooding, inundation, and sea level rise.

Geography


VA
NC
SC
N


Danville
Durham
Rocky Mount
North Carolina
Raleigh
Greenville
Albemarle Sound
Roanoke Island
Pamlico Sound
Fayetteville
Jacksonville
Morehead City
Bogue Island
Wilmington

Management Team: 11 Members

- **NC Sea Grant:** John Fear, Chair
- **NOAA:** National Centers for Coastal Ocean Science (NCCOS), National Weather Service (NWS): Carolyn Currin, David Glenn
- **North Carolina:** National Estuarine Research Reserve (NERR), Division of Coastal Management (DCM): Rebecca Ellin, Tancred Miller, Brandon Puckett
- **University of NC, Chapel Hill-Institute of Marine Sciences (UNC-IMS):** Nathan Hall
- **Duke University Marine Lab**: Justin Ridge
- **Coastal Studies Institute**: Reide Corbett
- **City of Jacksonville, NC**: Paula Farnell
- **SE Coastal Ocean Observing Regional Association (SECOORA):** Jennifer Dorton

Management Issues of Concern

- Sea level rise
- Coastal erosion
- Flooding
- Storm surge
- Habitat loss
- Water quality
- Restoration/mitigation
- Coastal resilience

Engaging Partners

2013 NCSSC Research and Monitoring Coordination Workshop, Beaufort, NC

2017 NCSSC Partners Meeting, Beaufort, NC

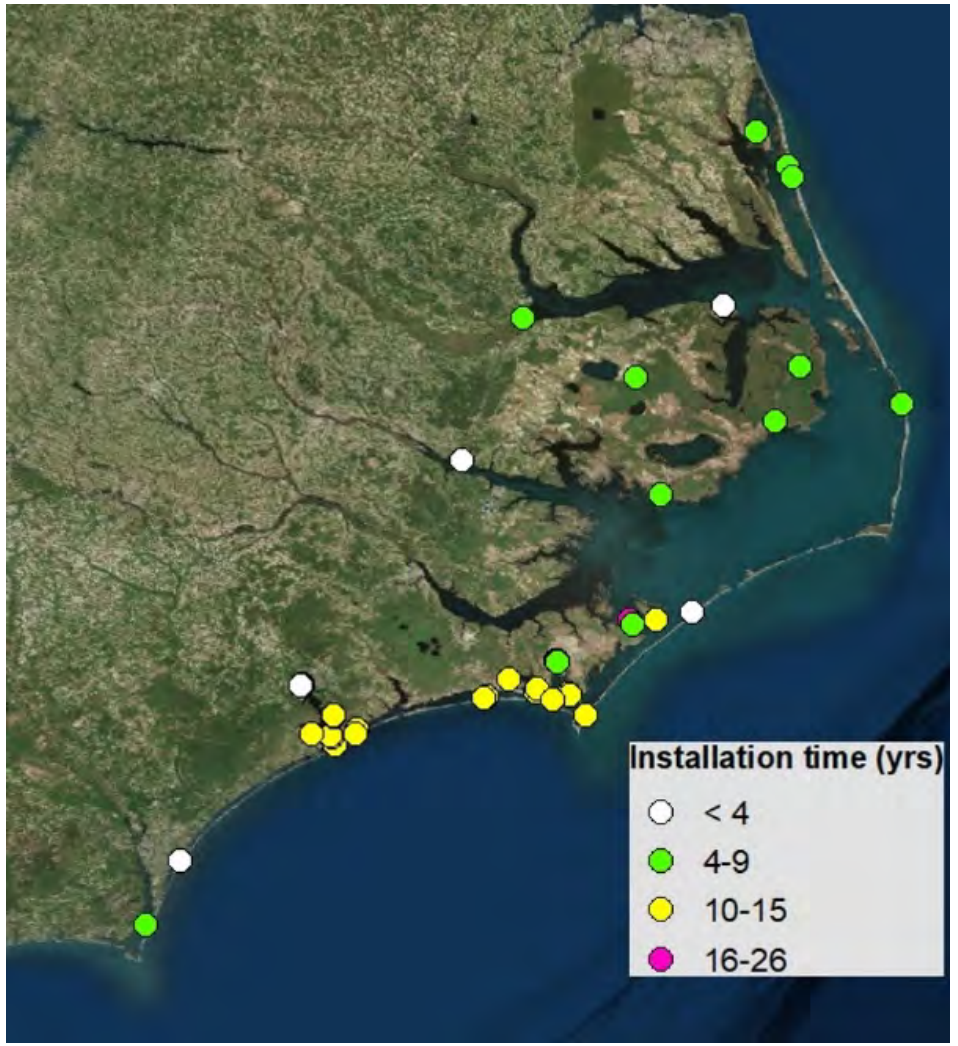
Research and Monitoring

NOAA Ecological Effects of Sea Level Rise

- Developing and Evaluating the Coastal Recovery from Storms Tool (CReST)
  PI: Peter Ruggerio, Oregon State University
- Understanding and predicting changes in coastal marsh ecosystem services
  PI: Christine Voss, UNC-Institute of Marine Science

Collaboration: NC SET Community of Practice

Research Staff from the N.C. Coastal Reserve use a SET at a reserve site to measure changes in the marsh's surface elevation.

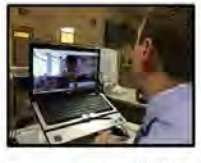


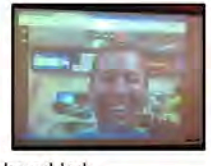
SET locations in coastal North Carolina, Source: Jenny Davis, NOAA, National Centers for Coastal Ocean Science

Outreach with Partners

NORTH·CAROLINA AQUARIUMS

Google Hangouts
Virtual Visit
National Weather Service
5th grade
Limited slots available!
Contact: erik.heden@noaa.gov if you have questions





*Future grades and/or visits may be added after the holidays based on interest level

National Weather Service
Newport/Morehead City, NC
www.weather.gov/mhx

Communication

Nov. 2016 Volume 4, Issue 4

NORTH CAROLINA

Sentinel Site Quarterly

North Carolina Sentinel Site Cooperative

Fall 2016

In This Issue

Marine Debris
Seagrass Study
Risk Webinar
NCSSC Meeting

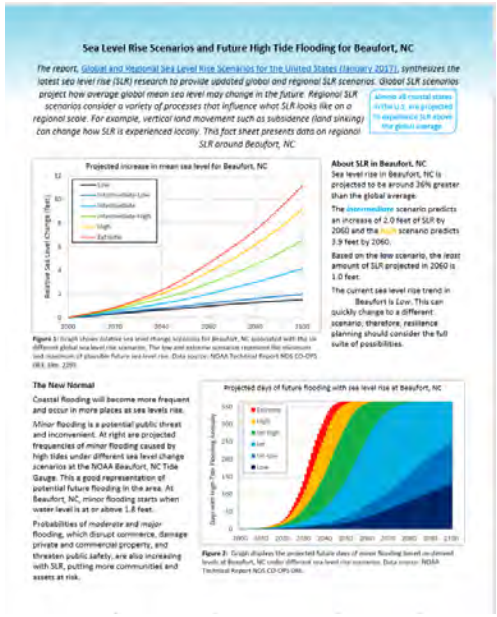
Contact Jennifer Dorton if you have articles or events that you would like to include in the next edition. Previous Quarterly Newsletters are on the NC DEQ website.

Marine Debris Clean-up at Rachel Carson Reserve

A large piling that washed into the NERR Rachel Carson Reserve required many hands to remove. Photo credit: *NC Coastal Reserve*.

Community members and volunteers, organized by Paula Gillikin, NERR Rachel Carson Site Manager, worked throughout September and October to remove over 10,500 pounds of medium and large debris items from the Reserve. The NOAA Marine Debris Program provided funding for mapping, medium and large pieces of debris, removal, and monitoring

Quarterly newsletter



Sea Level Rise Scenarios and Future High Tide Flooding for Beaufort, NC

The report, Global and Regional Sea Level Rise Scenarios for the United States (January 2017), synthesizes the latest sea level rise (SLR) research to provide updated global and regional SLR scenarios. Global SLR scenarios project how average global mean sea level may change in the future. Regional SLR scenarios consider a variety of processes that influence what SLR looks like on a regional scale. For example, vertical land movement such as subsidence (land sinking) can change how SLR is experienced locally. This fact sheet presents data on regional SLR around Beaufort, NC.

Almost all coastal stories Arthur U.S. are projected to experience SLR above the global average.

Projected increase in mean sea level for Beaufort, NC

About SLR in Beaufort, NC

Sea level rise in Beaufort, NC is projected to be around 26% greater than the global average.

The intermediate scenario predicts an increase of 2.0 feet of SLR by 2060 and the high scenario predicts 3.9 feet by 2060.

Based on the low scenario, the least amount of SLR projected in 2060 is 1.0 feet.

The current sea level rise trend in Beaufort is Low. This can quickly change to a different scenario; therefore, resilience planning should consider the full suite of possibilities.

The New Normal

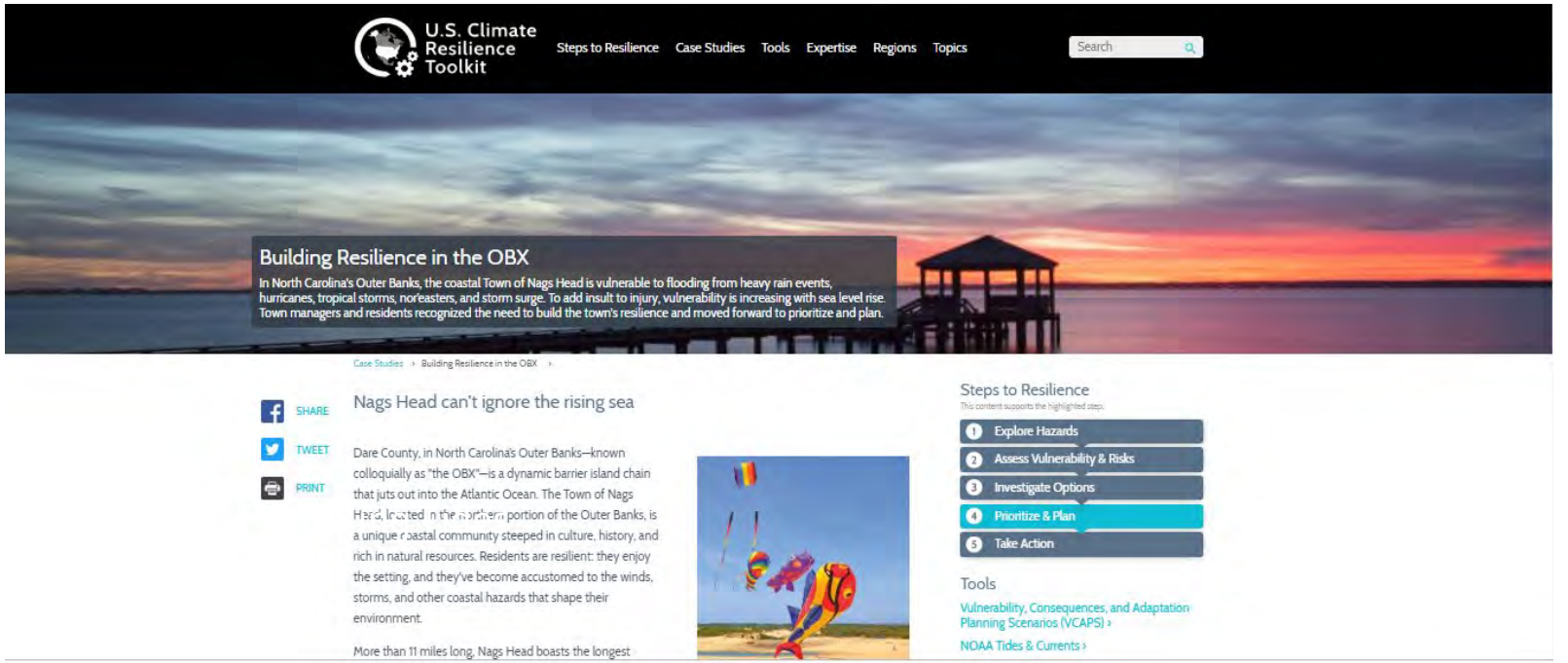
Coastal flooding will become more frequent and occur in more places at sea levels rise.

Minor flooding is a potential public threat and inconvenient. At right are projected frequencies of minor flooding caused by high tides under different sea level change scenarios at the NOAA Beaufort, NC Tide Gauge. This a good representation of potential future flooding in the area. At Beaufort, NC, minor flooding starts when water level is at or above 1.8 feet.

Probabilities of moderate and major flooding, which disrupt commerce, damage private and commercial property, and threaten public safety, are also increasing with SLR, putting more communities and assets at risk.

Projected days of future flooding with sea level rise at Beaufort, NC

Local SLR Two Pager



U.S. Climate Resilience Toolkit

Thank you for joining us today!
Please add your name to the sign-in sheet before you leave.

Sarah Spiegler
NC Sentinel Site Cooperative Coordinator
sespiegl@ncsu.edu
252.222.6307

NC Sentinel Site Cooperative

MARSHES

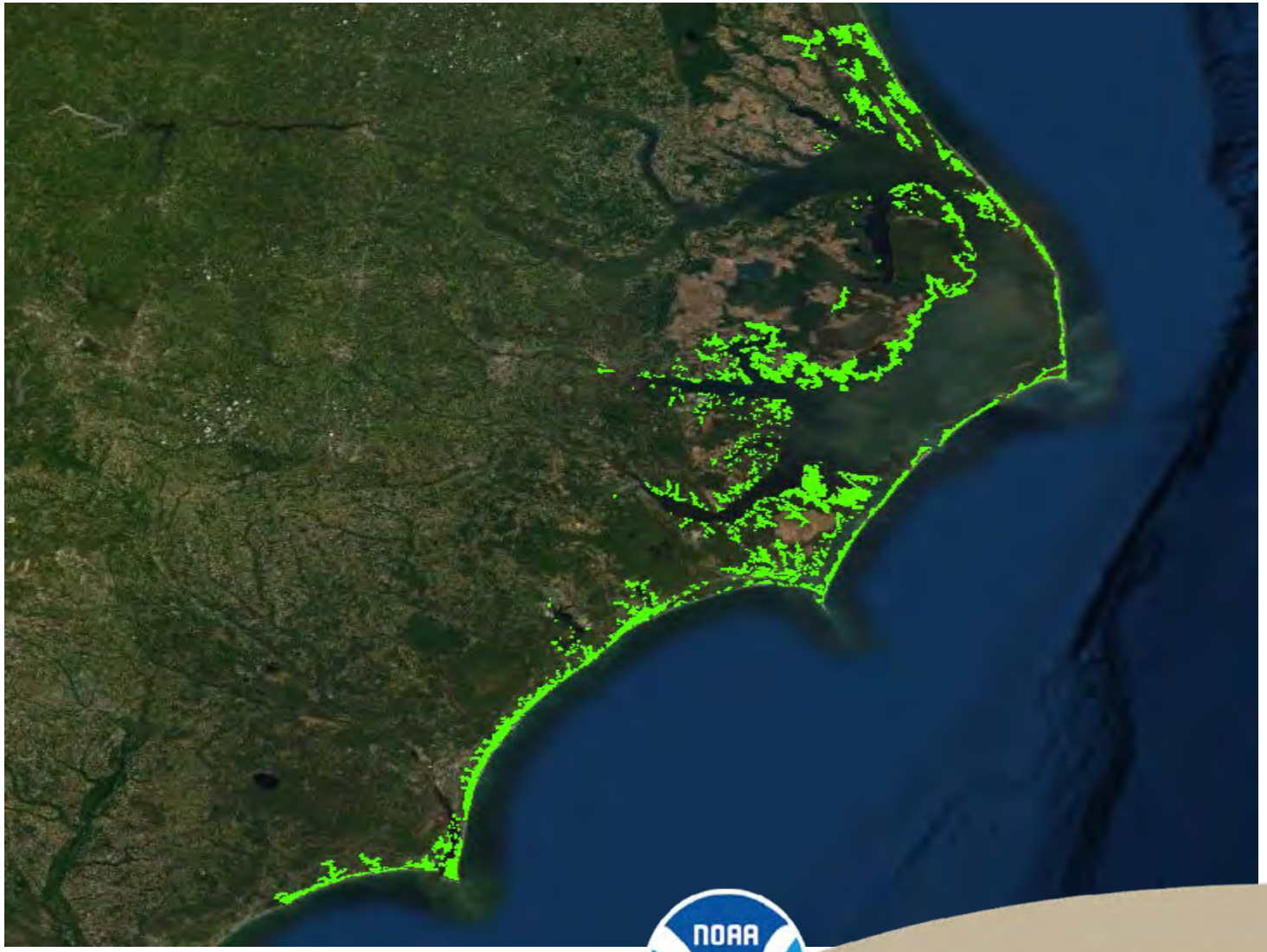
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

SENTINEL SITE COOPERATIVE
NORTH CAROLINA

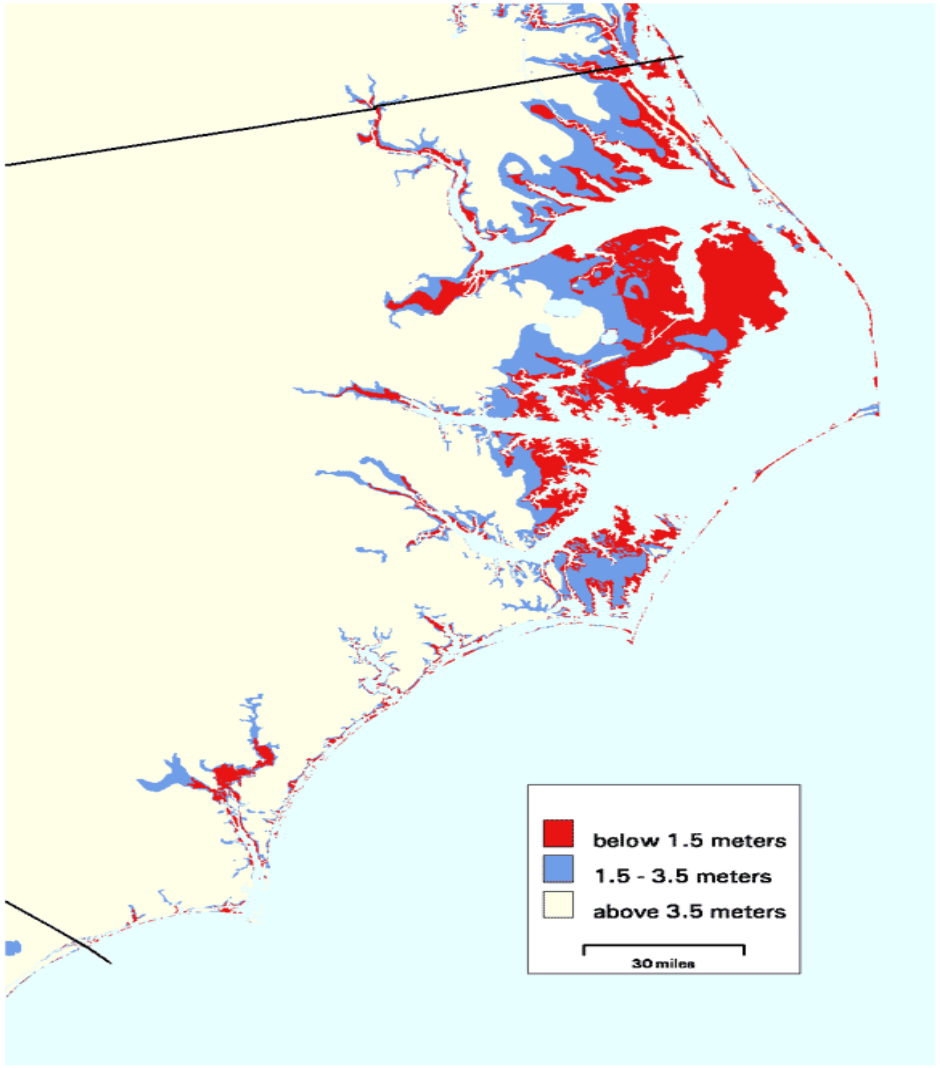
Sea Grant
North Carolina

North Carolina Coastal Wetlands in an Era of Sea Level Rise

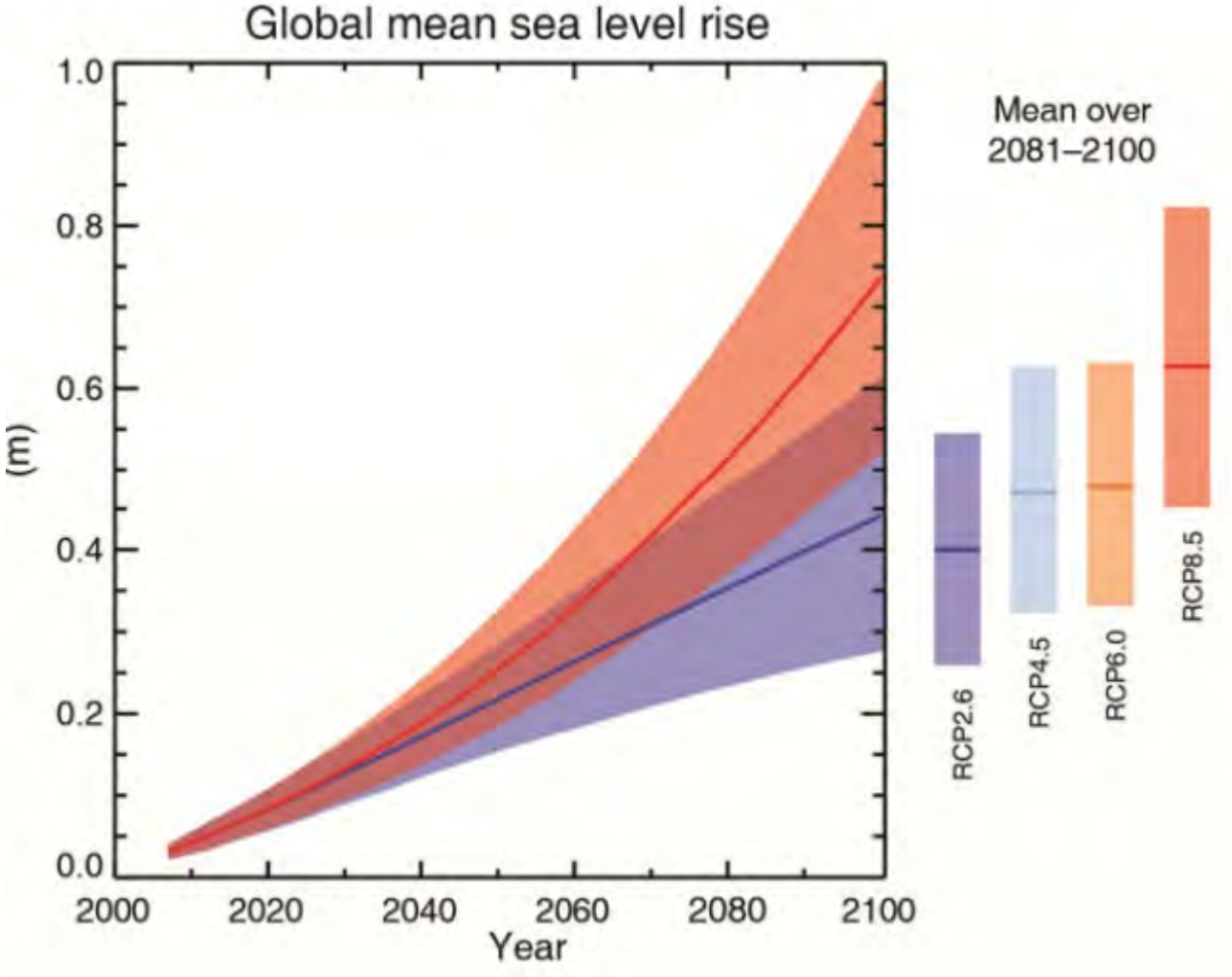
Jenny Davis and Carolyn Currin



Wetland Vulnerability



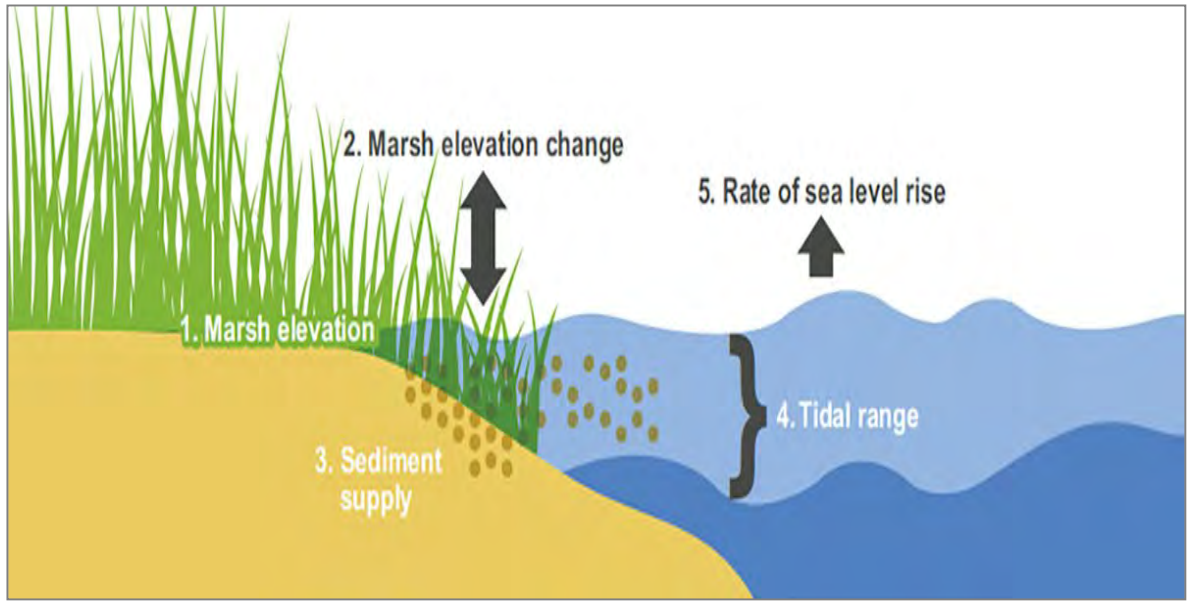
Titus & Richman, 2001



IPCC, 2018

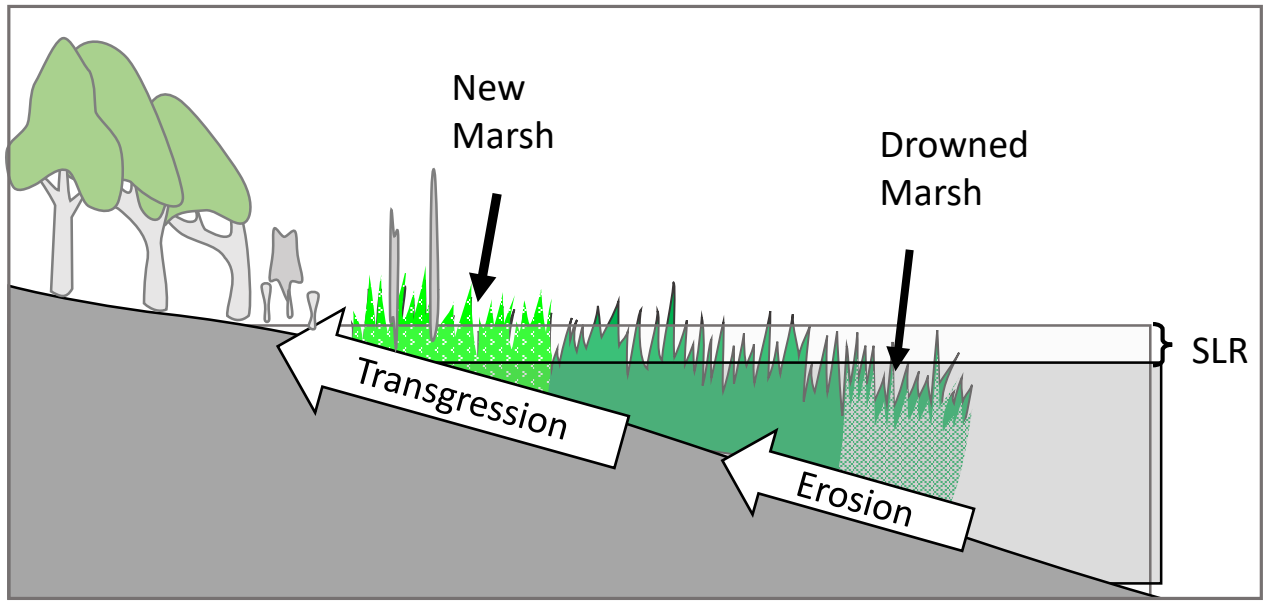
Possible Marsh Responses to Sea Level Rise

Keep Up



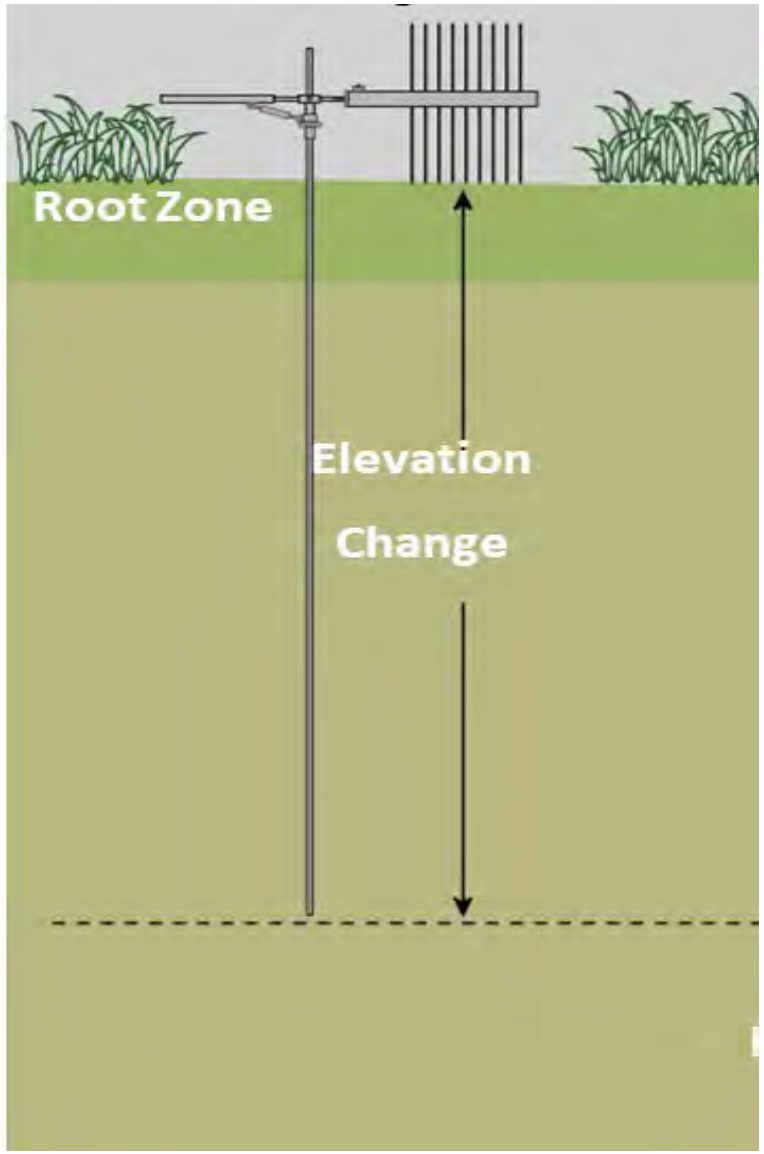
Requires Adequate Sediment Supply and Plant Biomass

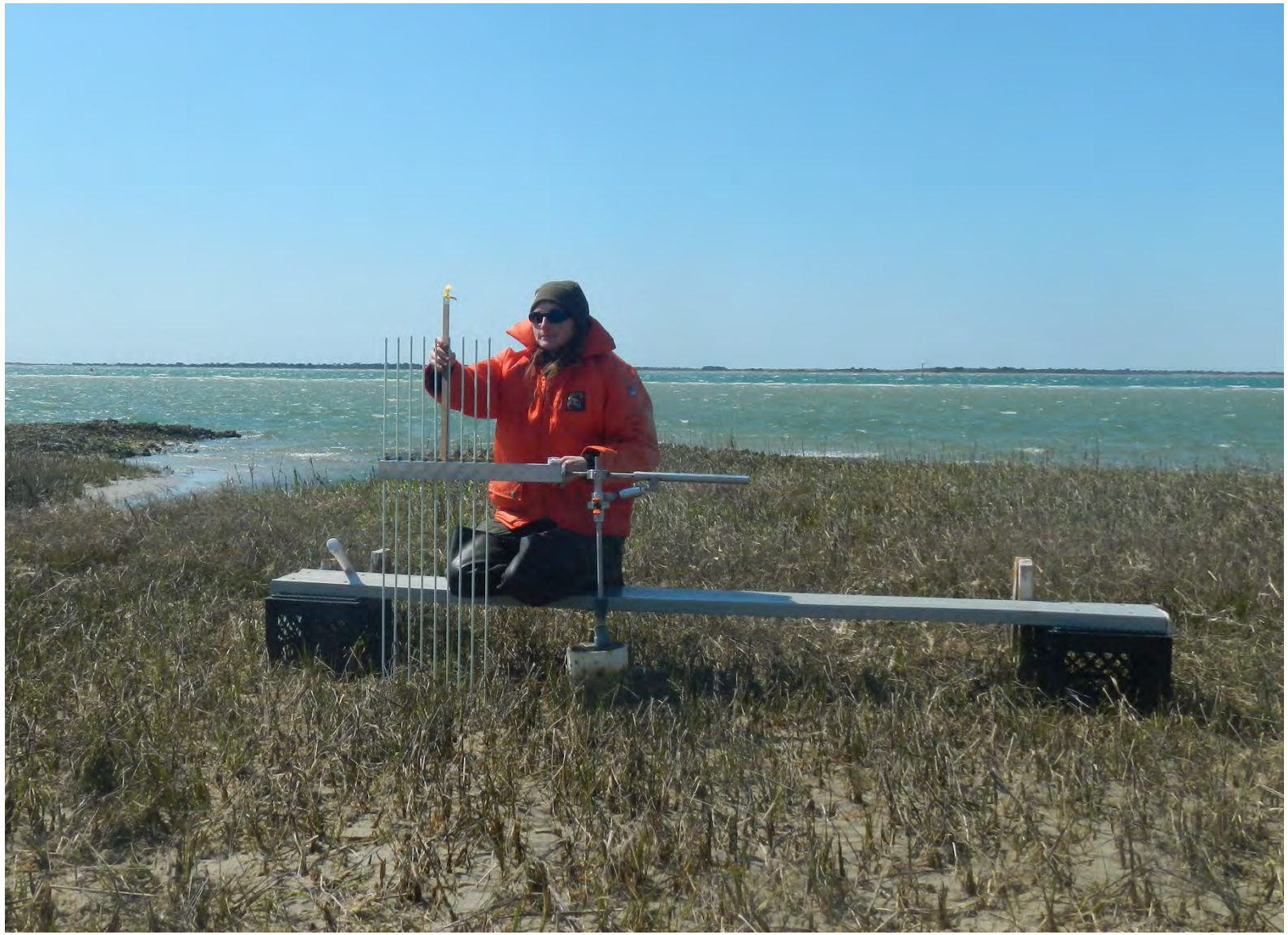
Migrate Inland



Requires undeveloped space to move into and no topographical barriers

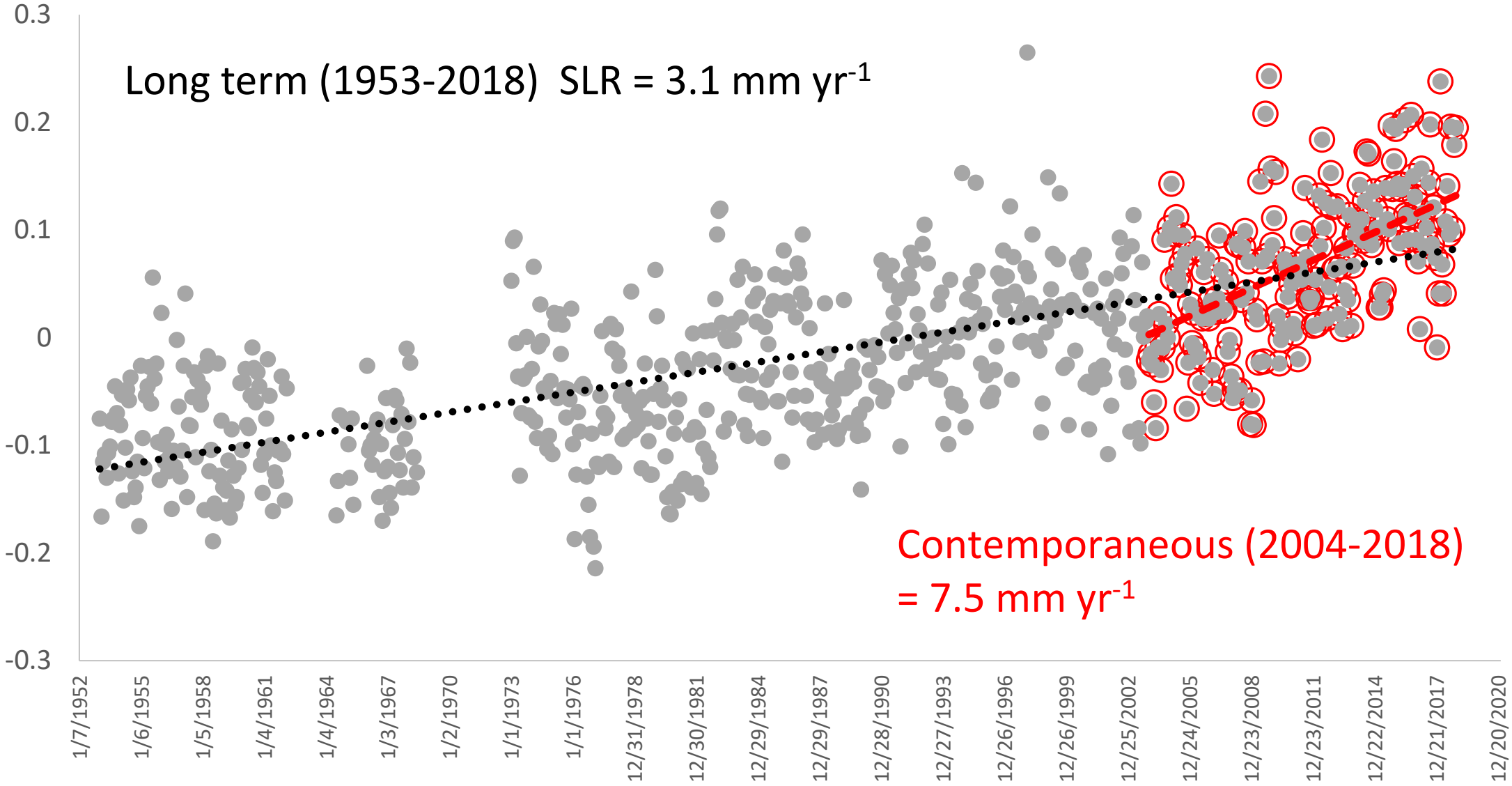
Surface Elevation Tables Detect mm-scale Change in Marsh Surface Elevation



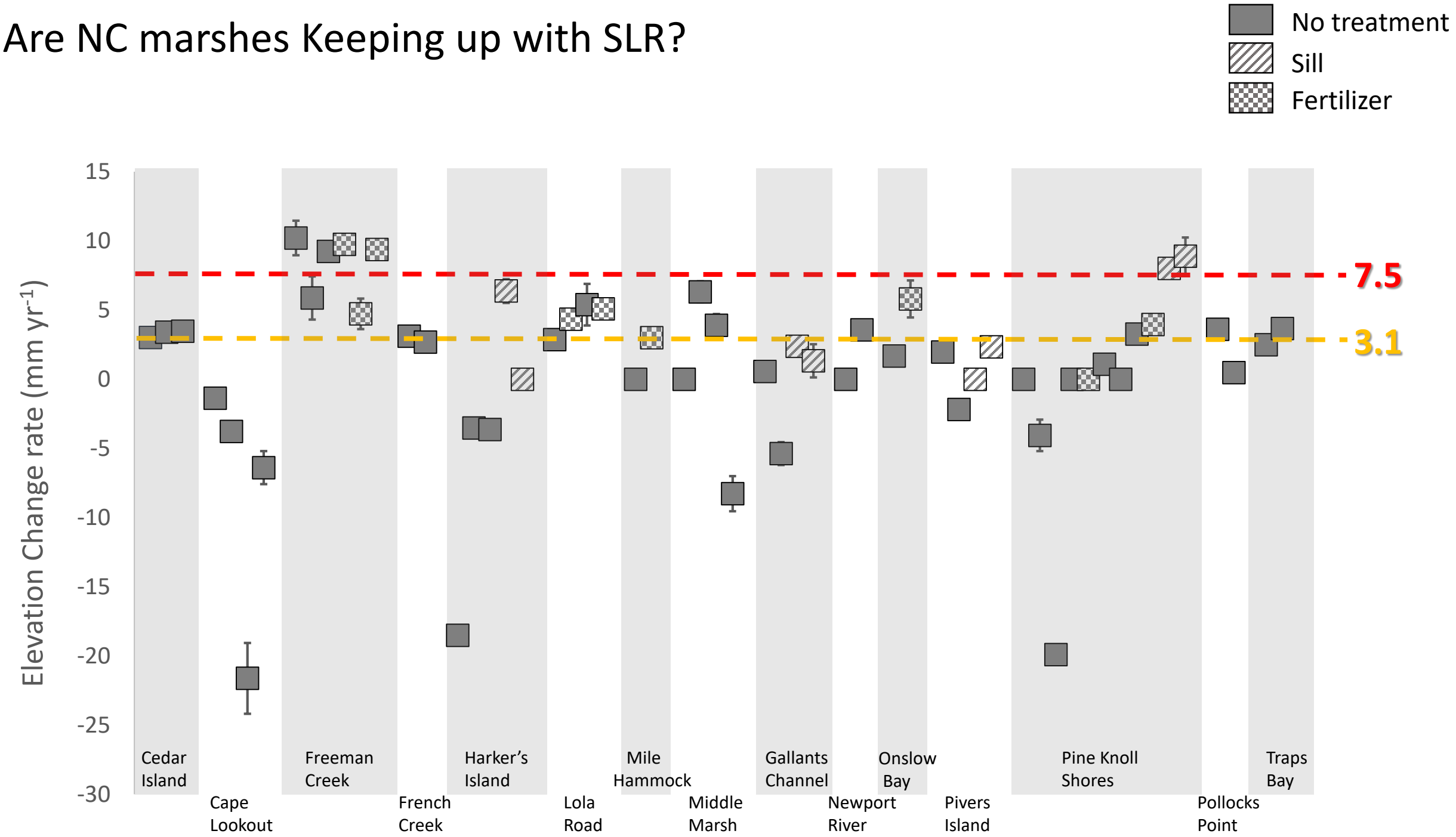


57 SETs: 8 in Marsh-Sill Living Shorelines, 9 fertilized, 40 with no associated treatment

Monthly Mean Sea Level (Beaufort NWLON)



Are NC marshes Keeping up with SLR?



Are NC marshes Keeping up with SLR?

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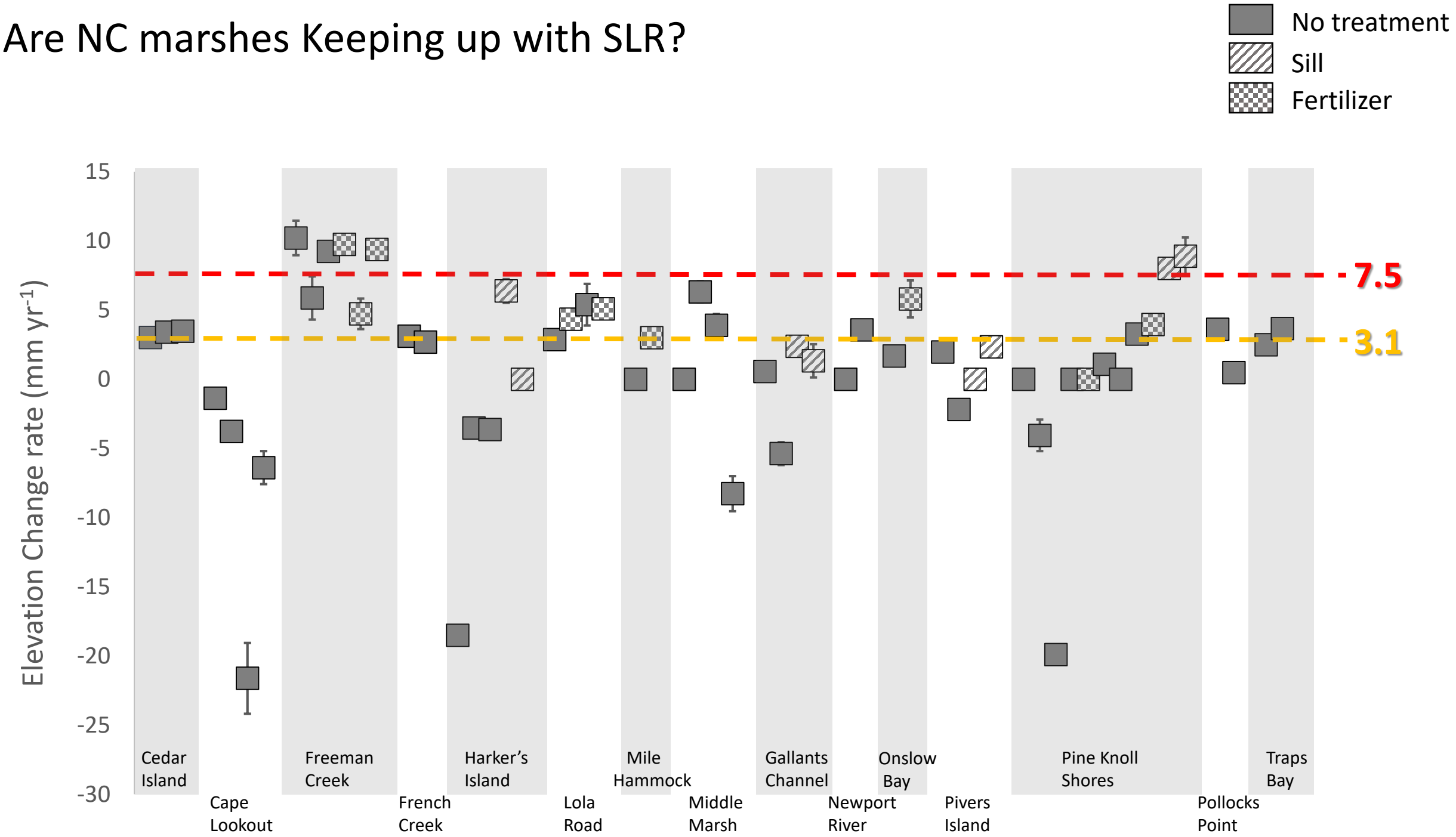
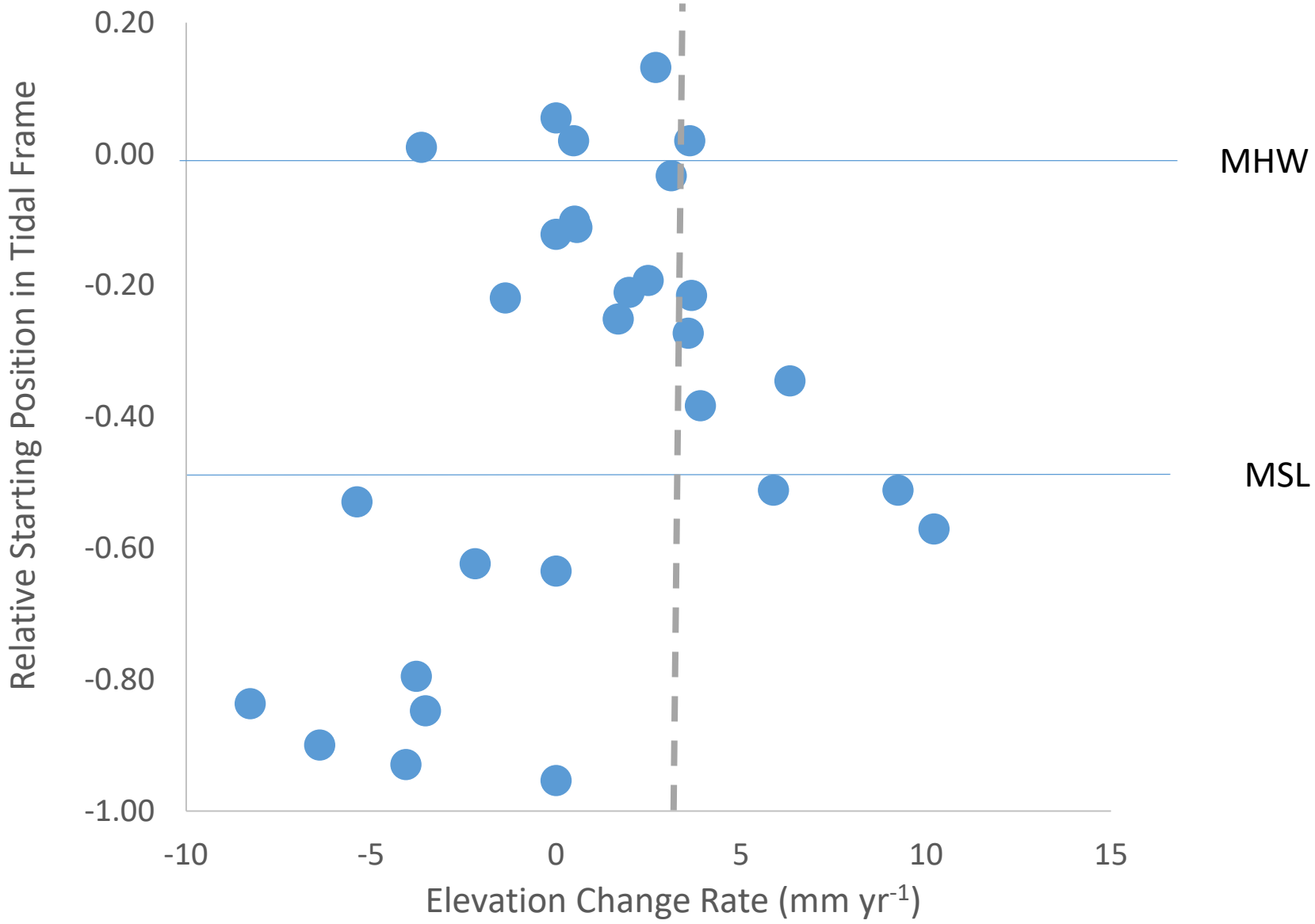
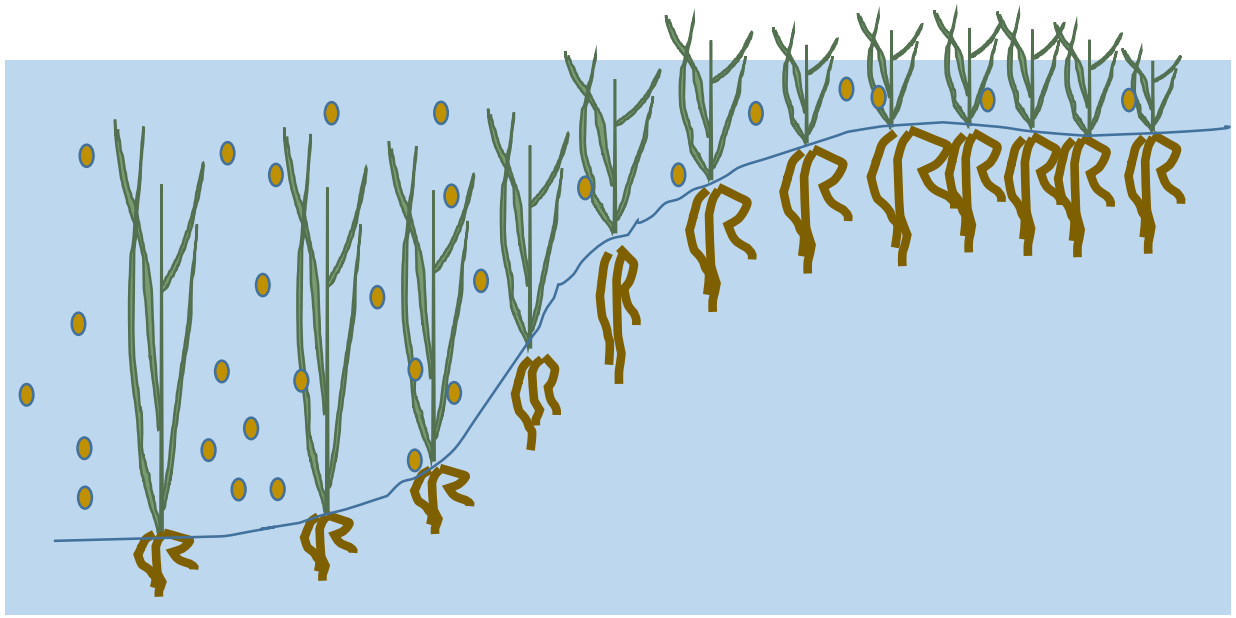


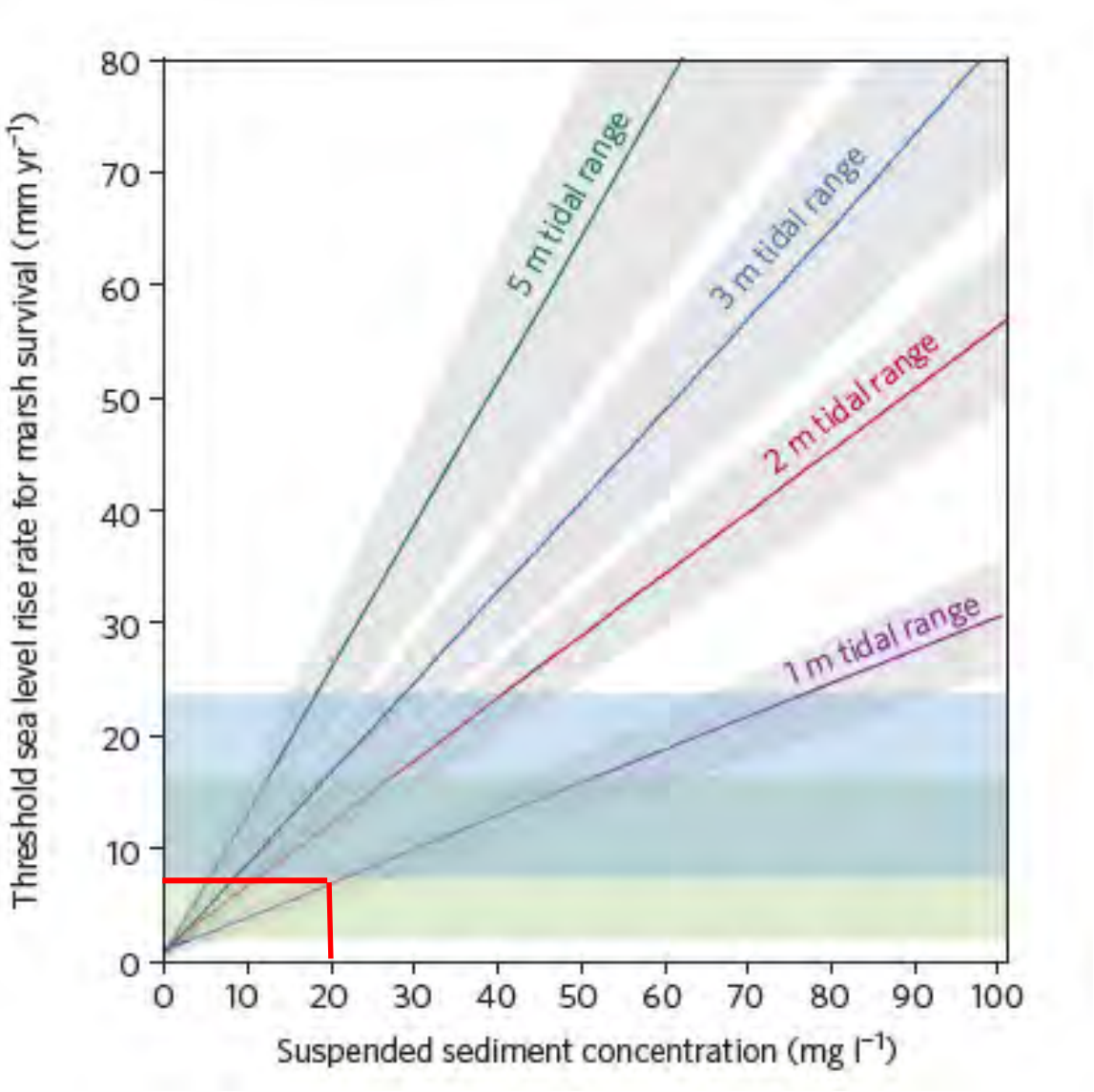
Marsh Starting Position Predicts Change Over Time



The Role of Sediment Supply

Marshes that are deeper in the tidal frame have more opportunity to trap sediment – but only if there is enough sediment available

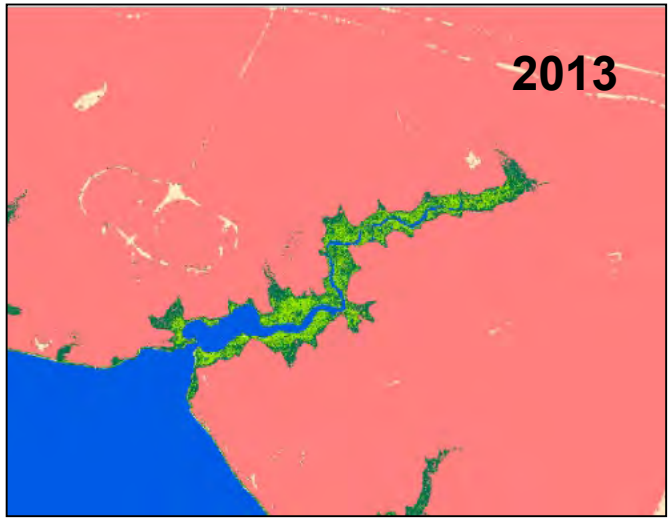


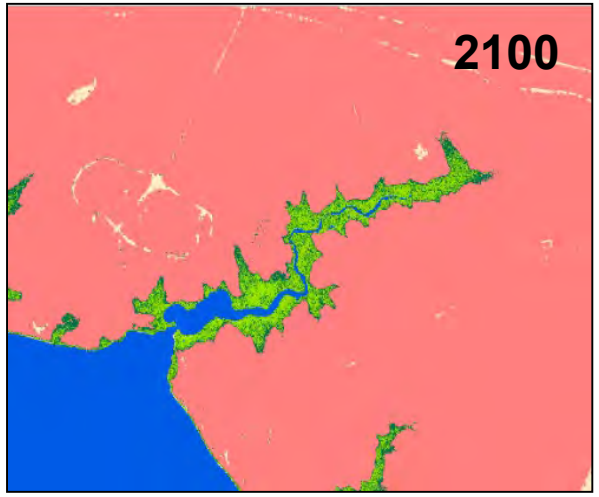


Kirwan et al 2016

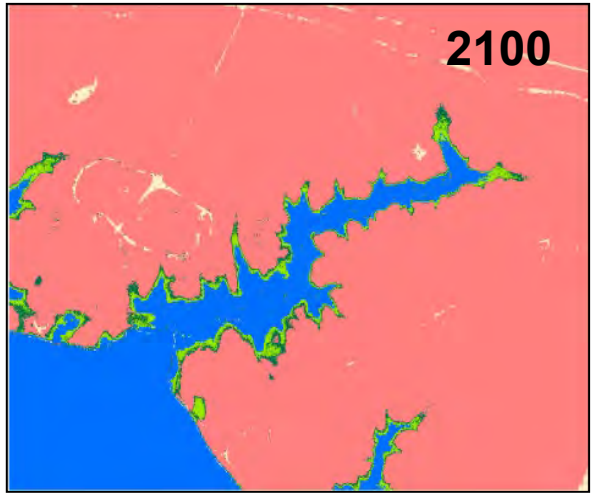
Will NC Marshes, Keep Up, Drown, or Migrate?

Traps Bay



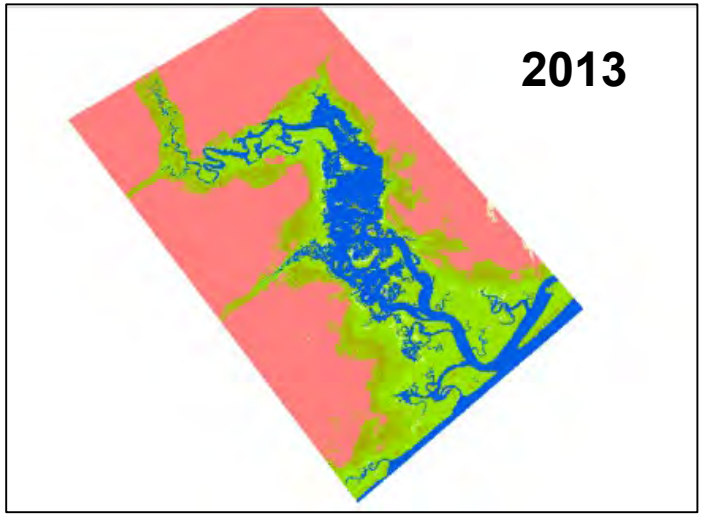


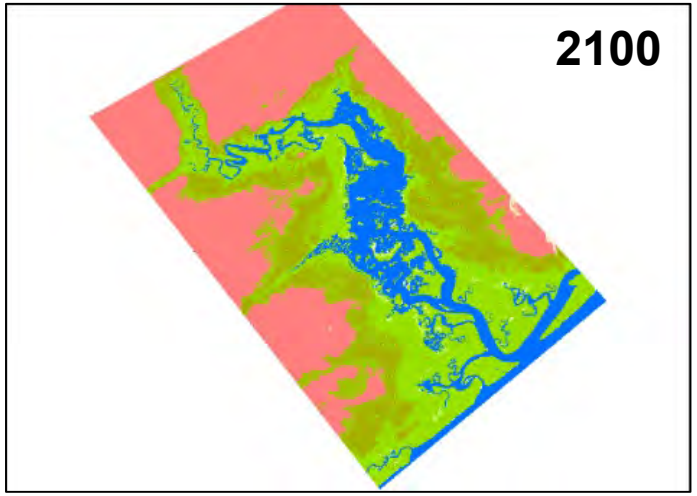
Lowest (0.3m)



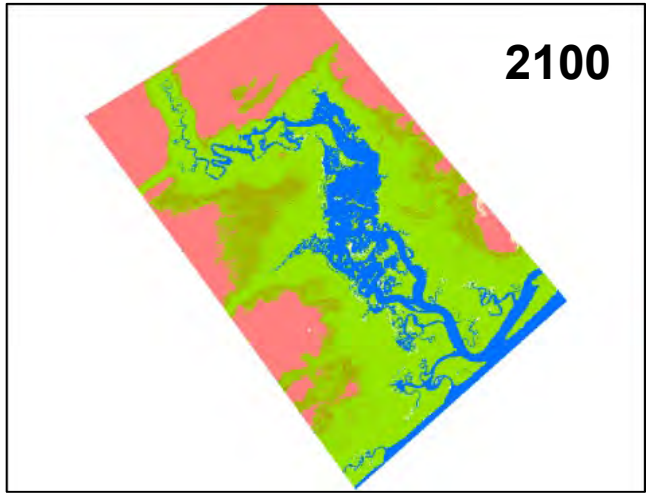
Medium (1.3 m)

Freeman Creek



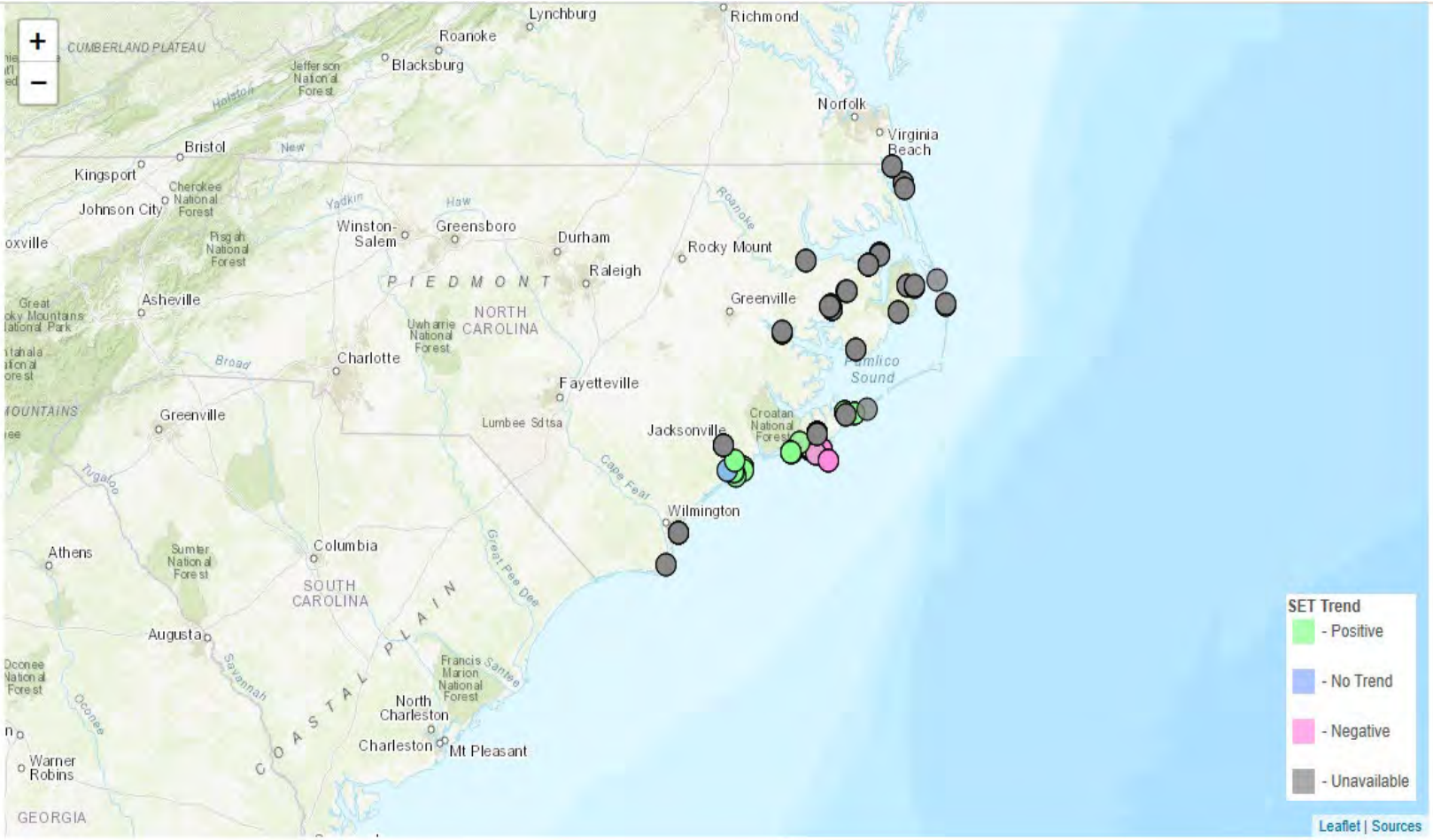


Lowest (0.3 m)



Medium (1.3 m)

NC Sentinel Site-wide SET database



Affiliation: Any | Type Of Institution: Any

Geomorphic Setting: Any | Salinity: Any

Marker Horizons: Any | Year Installed Range - Start: 1992 | End: 2019

Annual Data Available?: Any | SET Trend Rate: Any

Elevation Data: Any | Hydrologic Zone: Any

SET Type: Any | Vegetation Community Type: Any

Query | Reset | Download

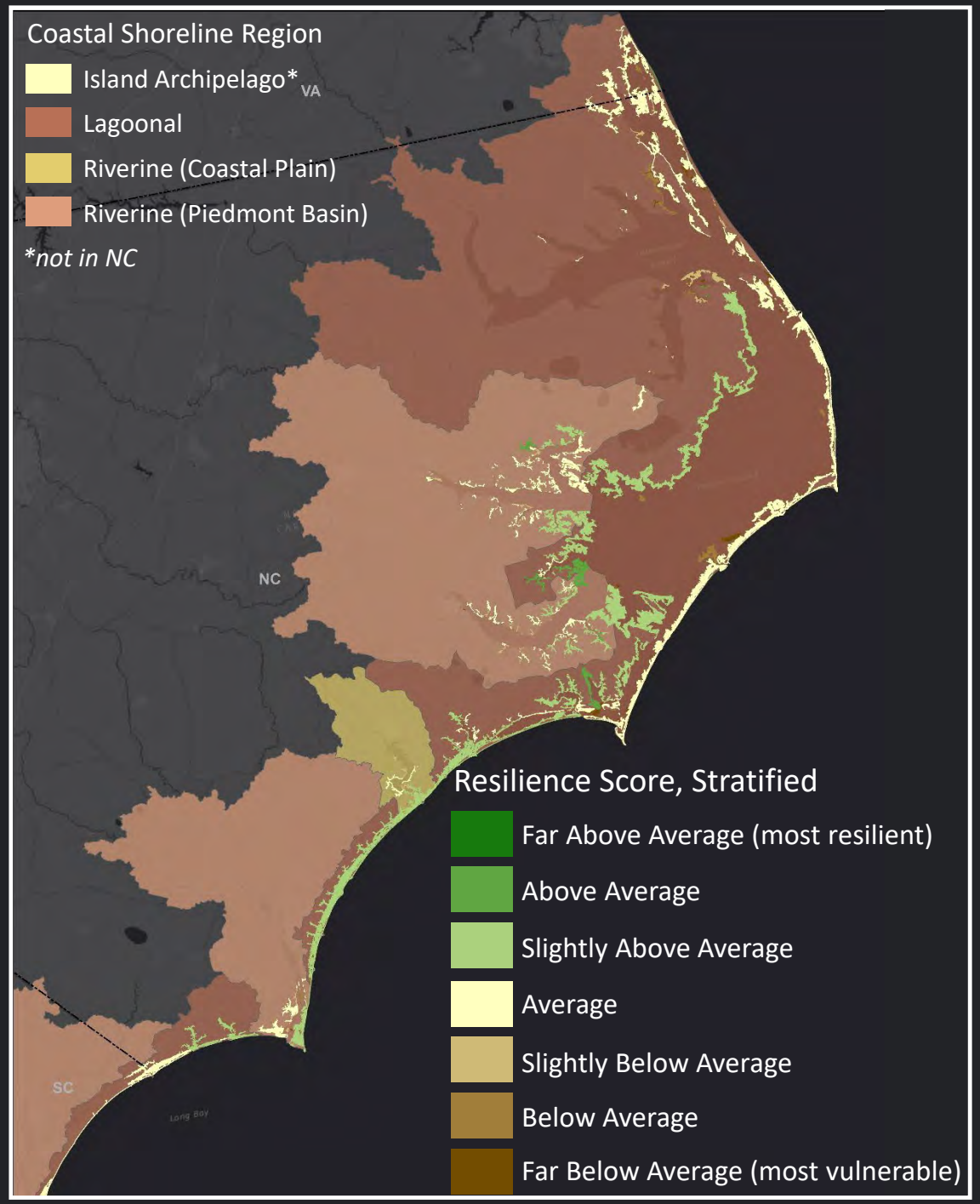
** Special thanks to Christine Voss (UNC) and Don Cahoon (USGS) for contributing data

Resilient Coastal Sites for Conservation in North Carolina and the South Atlantic United States

Brian Boutin
The Nature Conservancy, North Carolina Chapter

Mark Anderson & Analie Barnett
The Nature Conservancy, Eastern Conservation Science

The Nature Conservancy



It is Happening

SCIENCE CONNECTIONS →

SEA LEVEL RISE & GLOBAL WARMING

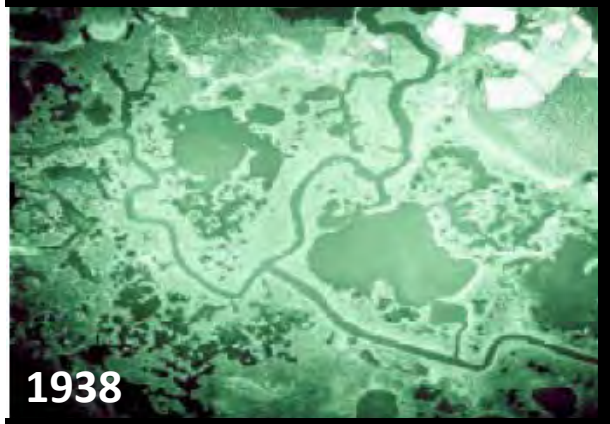
Sea levels in the U.S. are rising fastest along the East Coast and Gulf of Mexico.

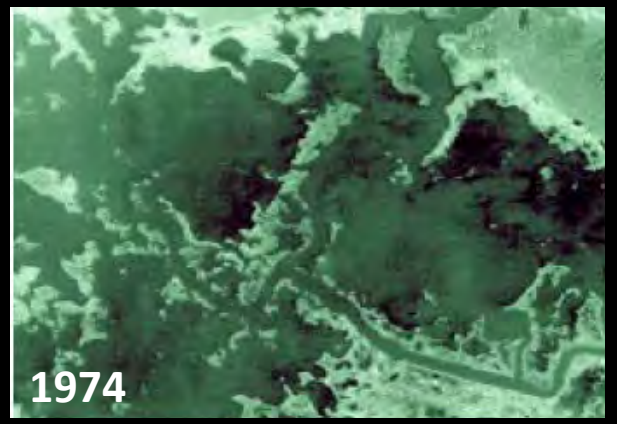
Local Sea Level Rise Over the Last 50 Years
(1963–2012)

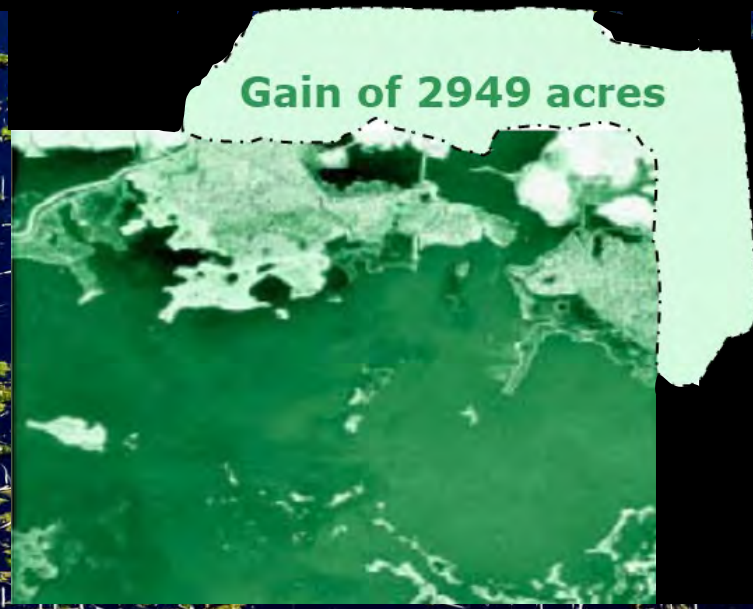
Global average sea level has increased 8 inches since 1880. The local rate varies depending on both global and local factors, including currents, ocean floor topography, variation in ocean density, and land uplift or susbsidence due to geological processes or human activities.

The Challenge

Blackwater National Wildlife Refuge (MD): Loss of 5,028 acres of tidal marsh, but gain of 2,949 acres at upland edge with 1’ SLR over 68 years (Lerner et al. 2013)



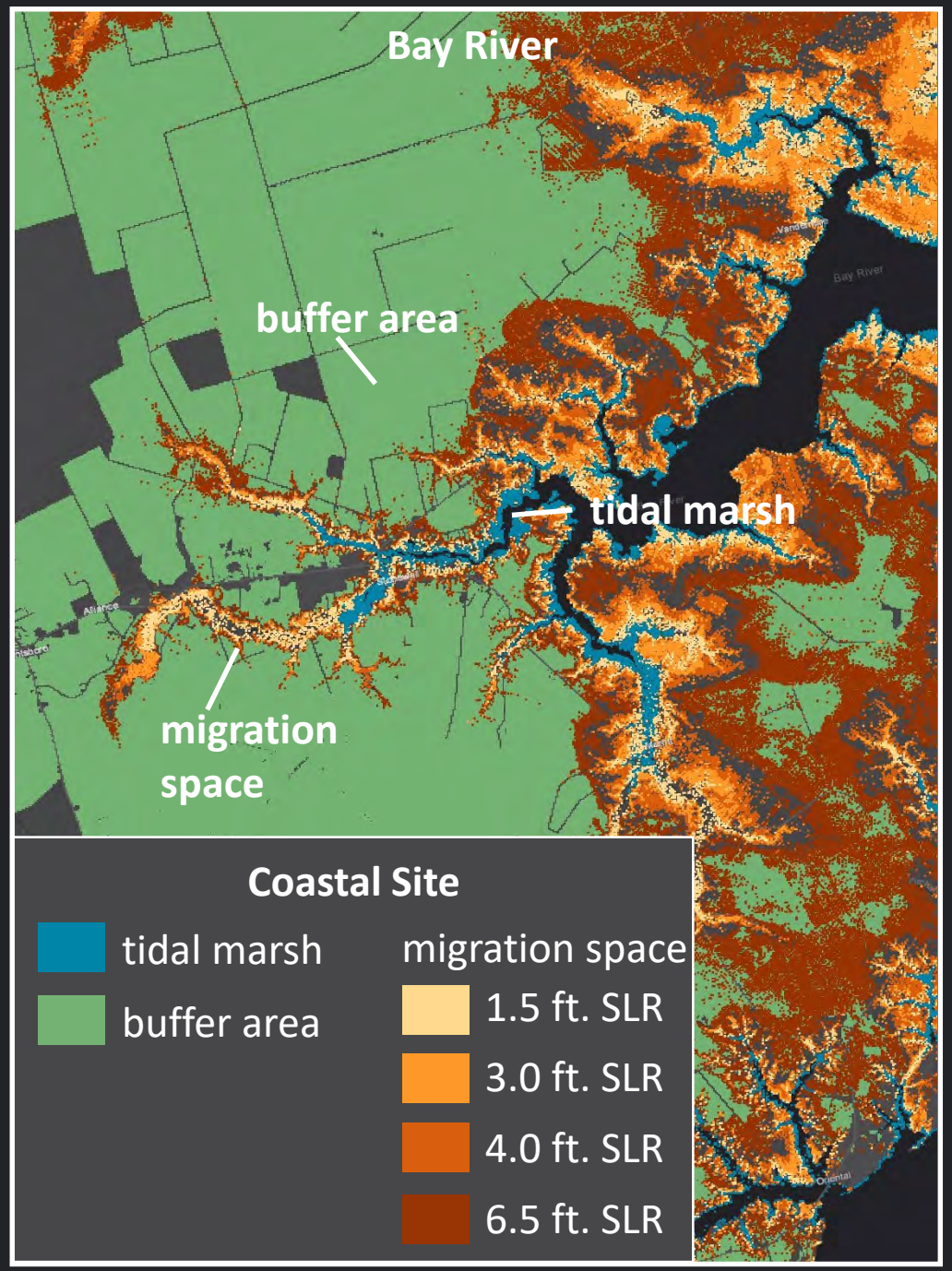


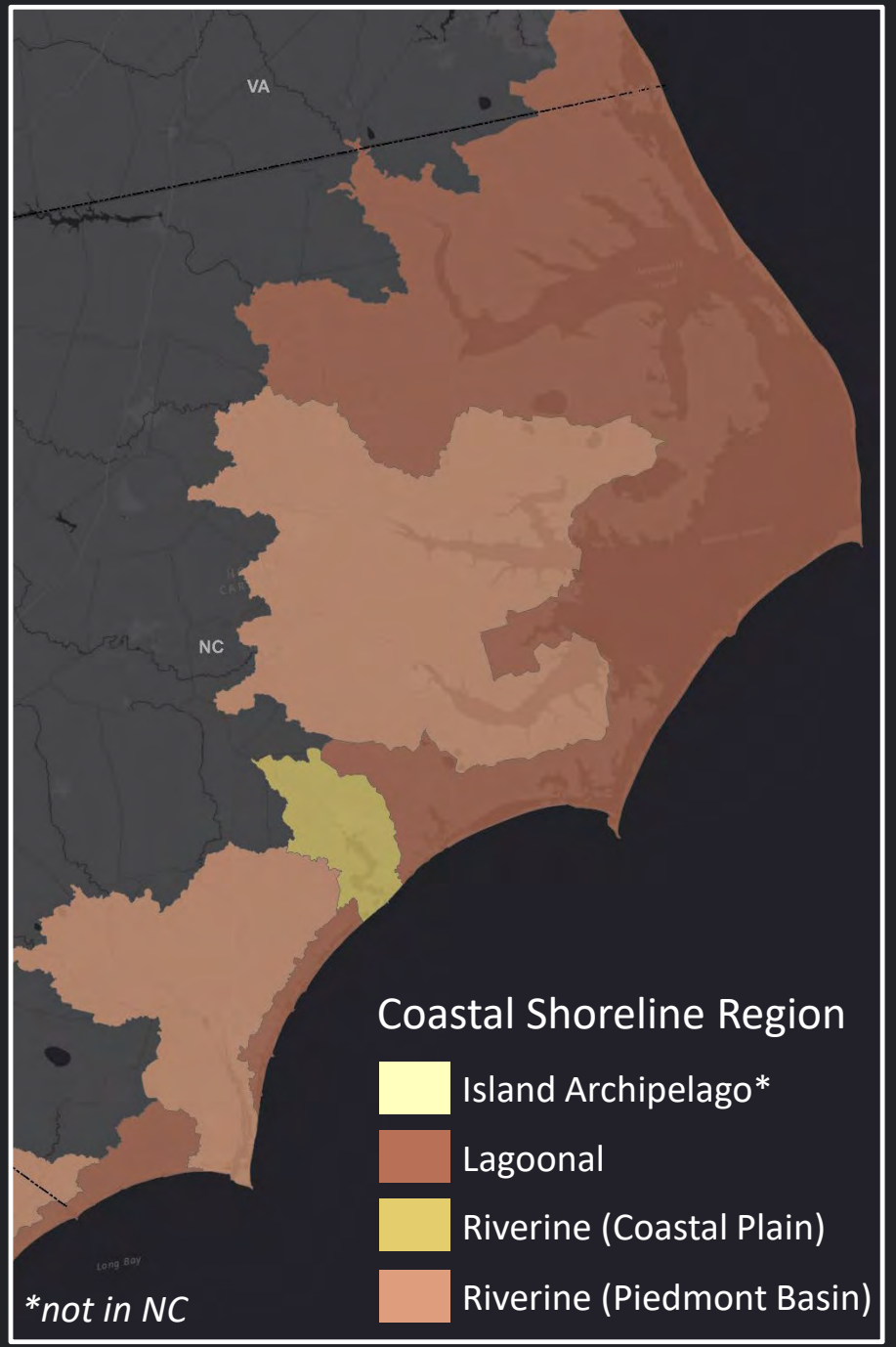


Dead loblolly pines cast shadows over salt marsh at Blackwater National Wildlife Refuge in Dorchester County, Md., on June 5, 2018. Rising seas result in salty water intruding on forested land and killing trees. (Photo by Will Parson/Chesapeake Bay Program)

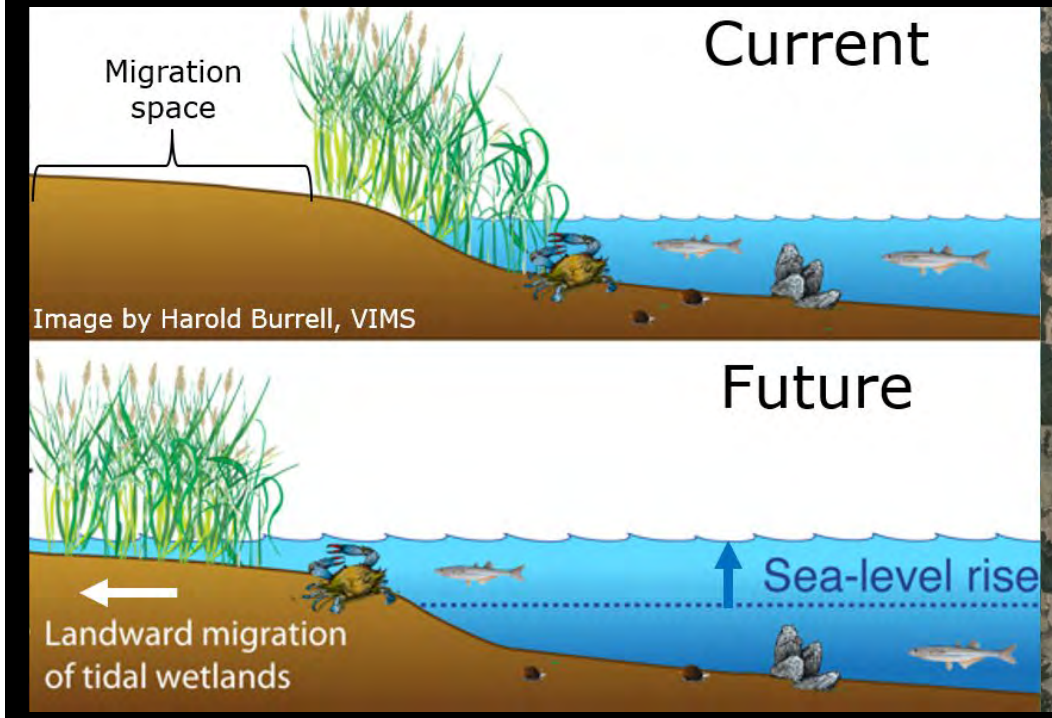
Lerner, J.A., Curson, D.R., Whitbeck, M. & Meyers, E.J. 2013. Blackwater 2100: A strategy for salt marsh persistence in an era of climate change. The Conservation Fund (Arlington, VA) and Audubon MD-DC (Baltimore, MD).

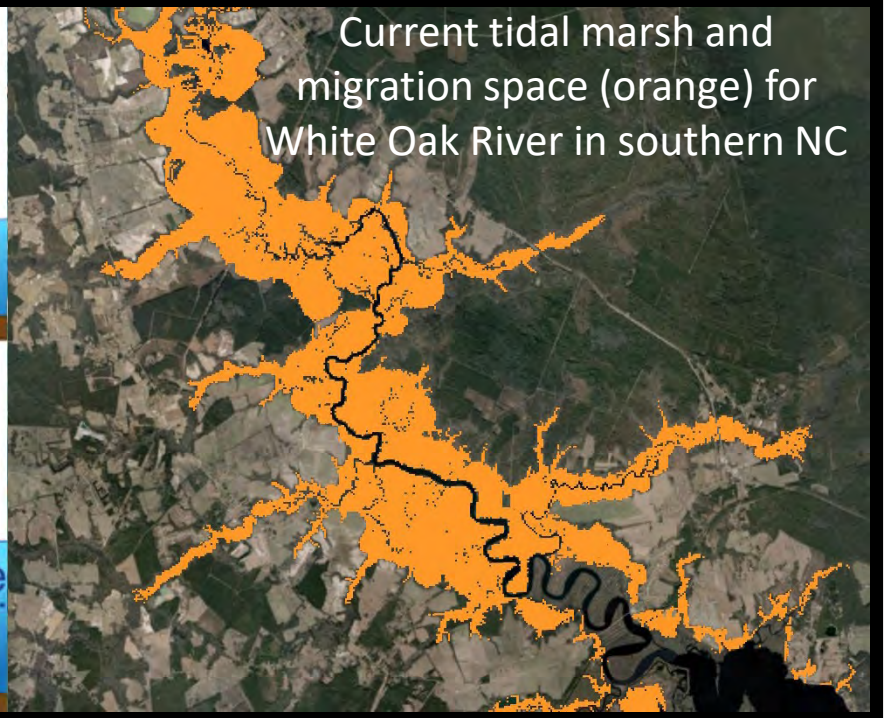
Coastal Sites & Coastal Shoreline Regions (CSRs)





Migration Space

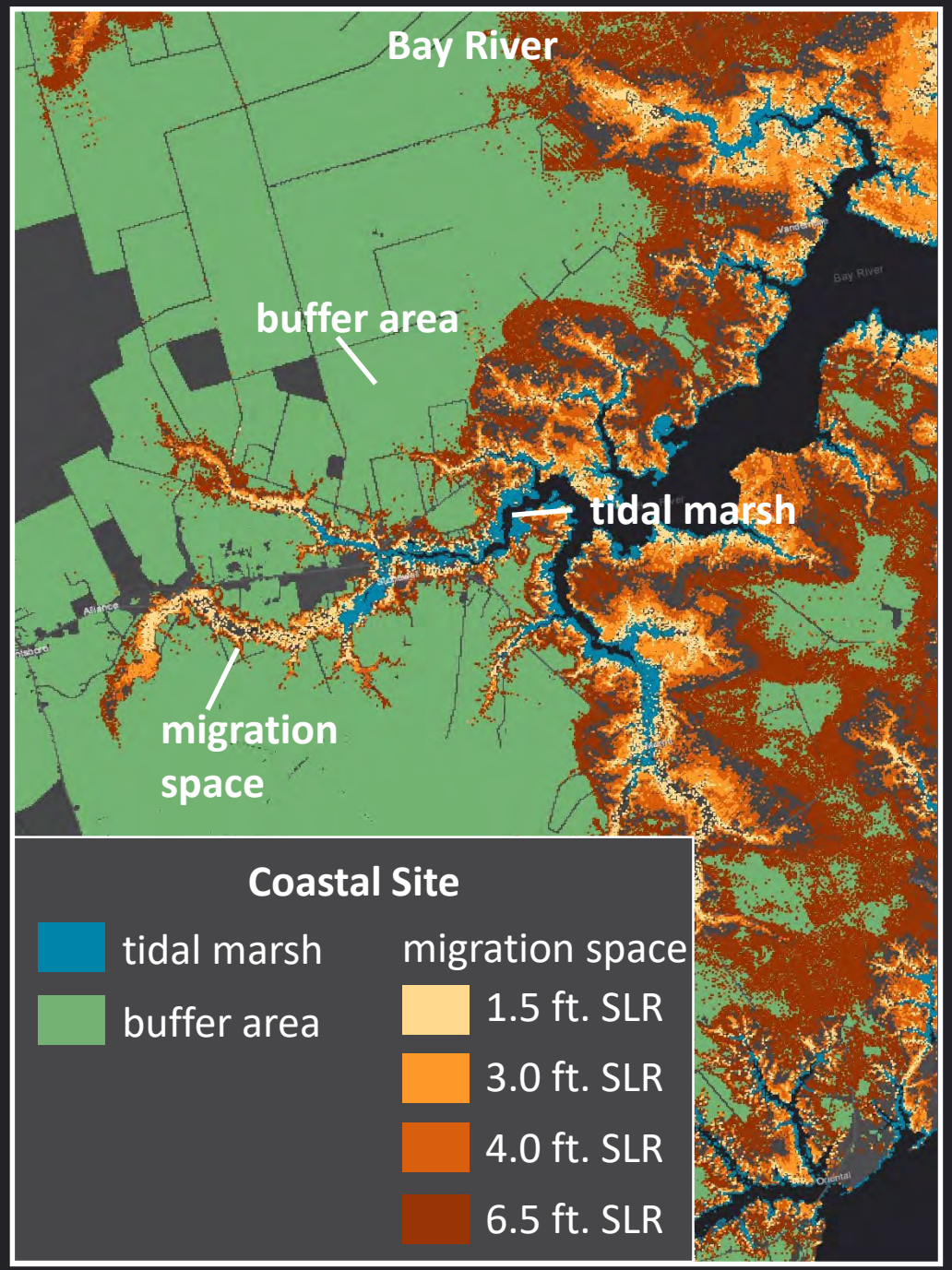




Adjacent, low-lying land suitable for supporting tidal habitats in the future, and into which current habitats could migrate as sea levels rise.

Calculated using NOAA SLR Viewer marsh migration data

What is a Resilient Coastal Site?



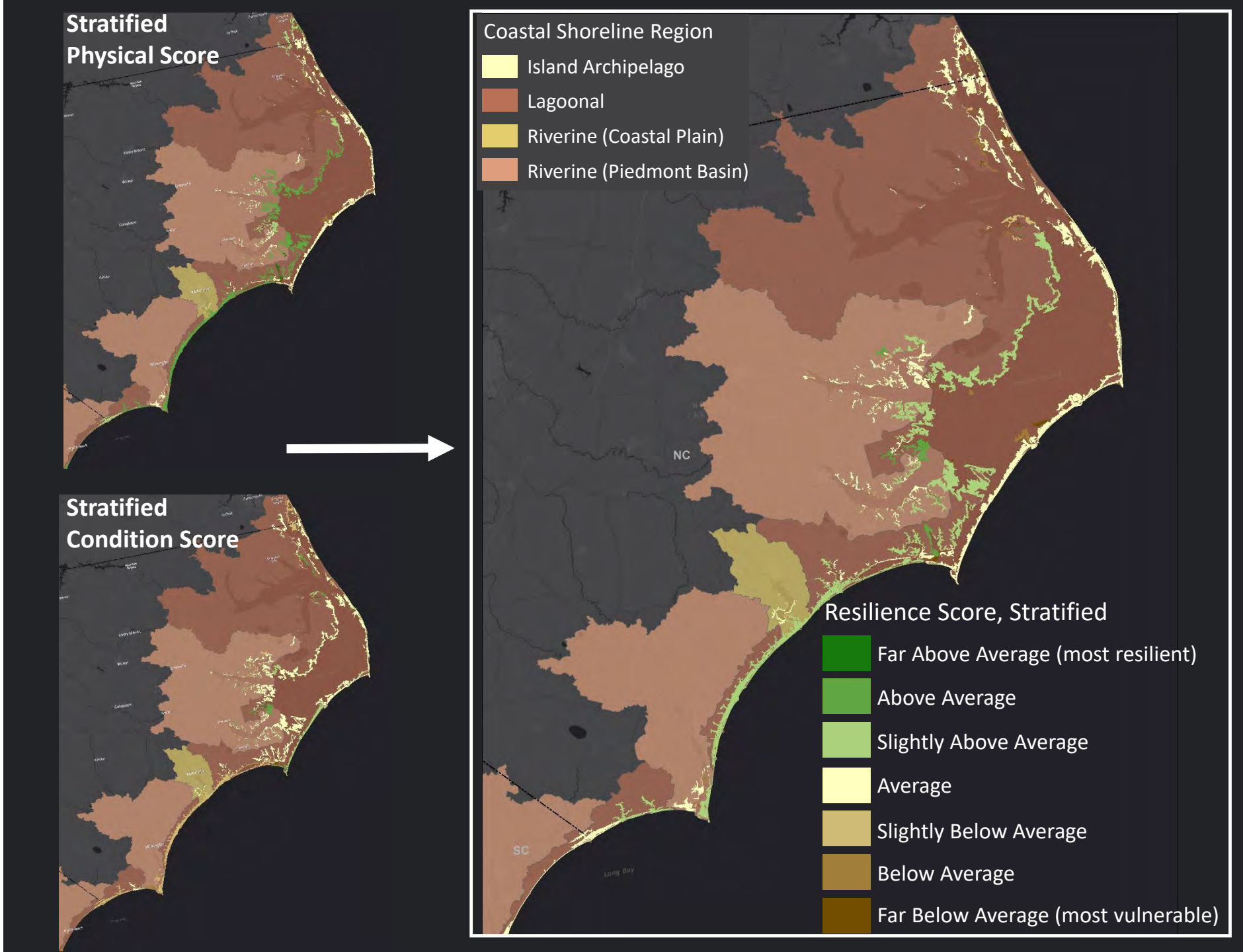
PHYSICAL ATTRIBUTES

- Large migration space
- Many future tidal classes
- Lots of shared upland edge with migration space
- Large tidal complex
- Large buffer area with diverse coastal landforms and maritime highlands

CONDITION ATTRIBUTES

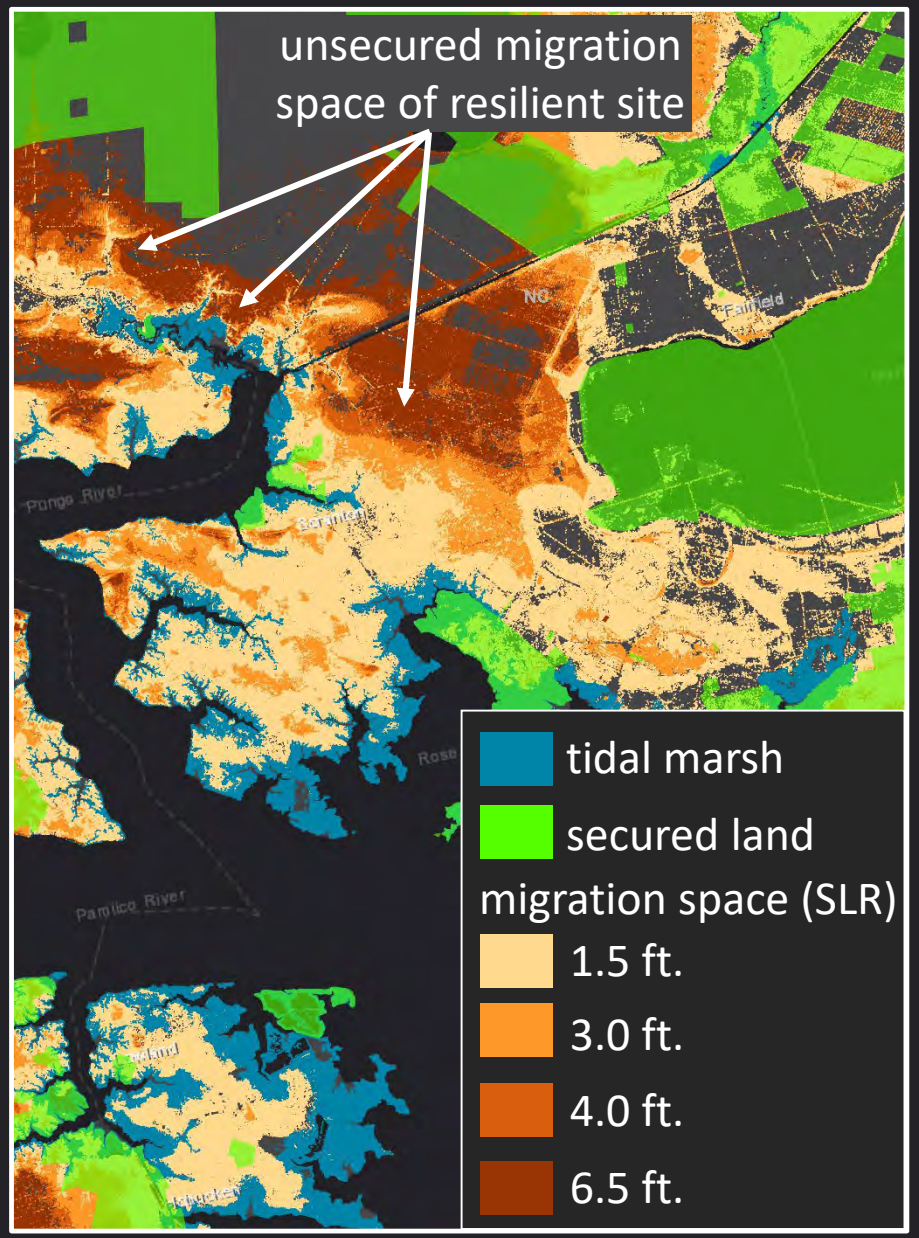
- Few anthropogenic barriers to marsh migration
- Positive sediment balance
- Good water quality index
- Minimal freshwater flow alteration
- Natural buffer area with high wetland connectivity

Resilience Scores (Stratified by CSR)



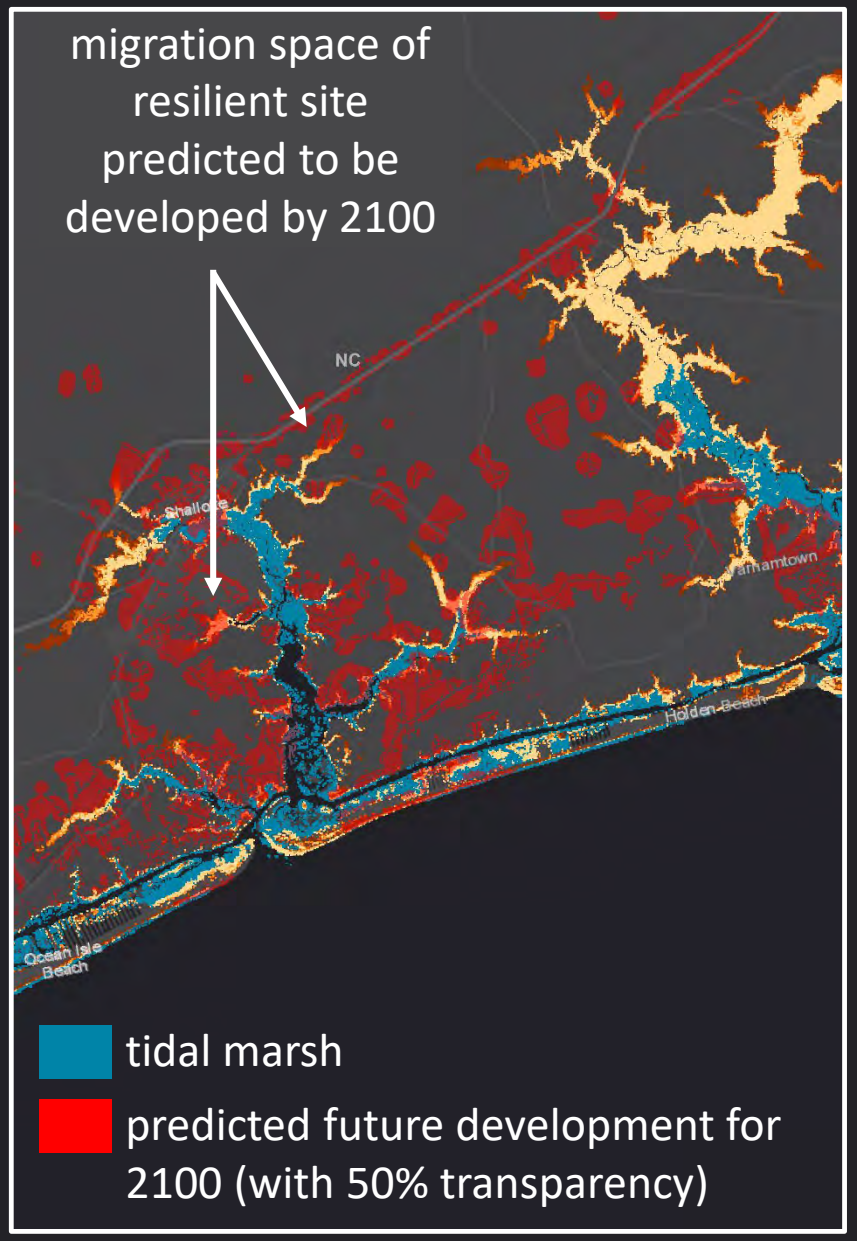
Using the Results

Land Protection



Pungo River

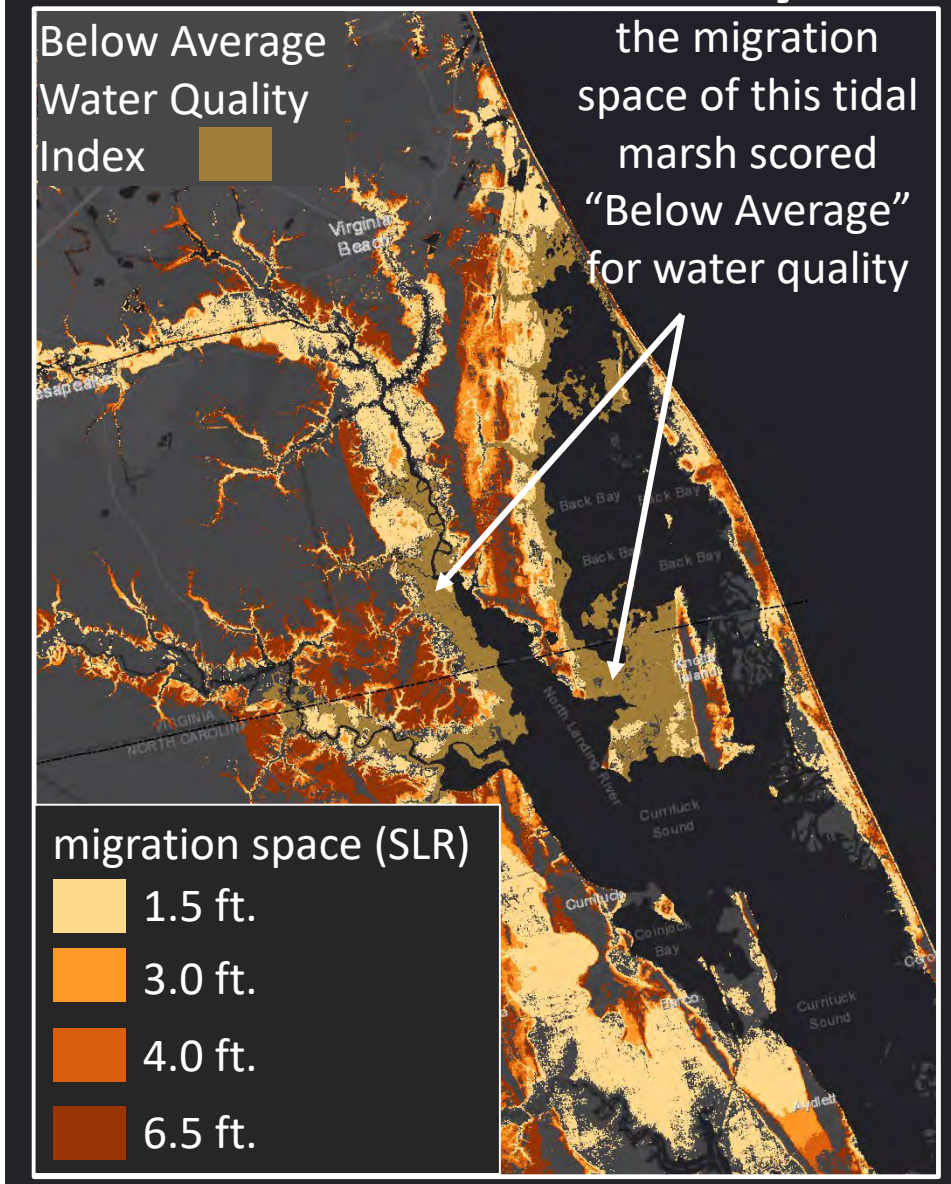
Future Development



Shallotte

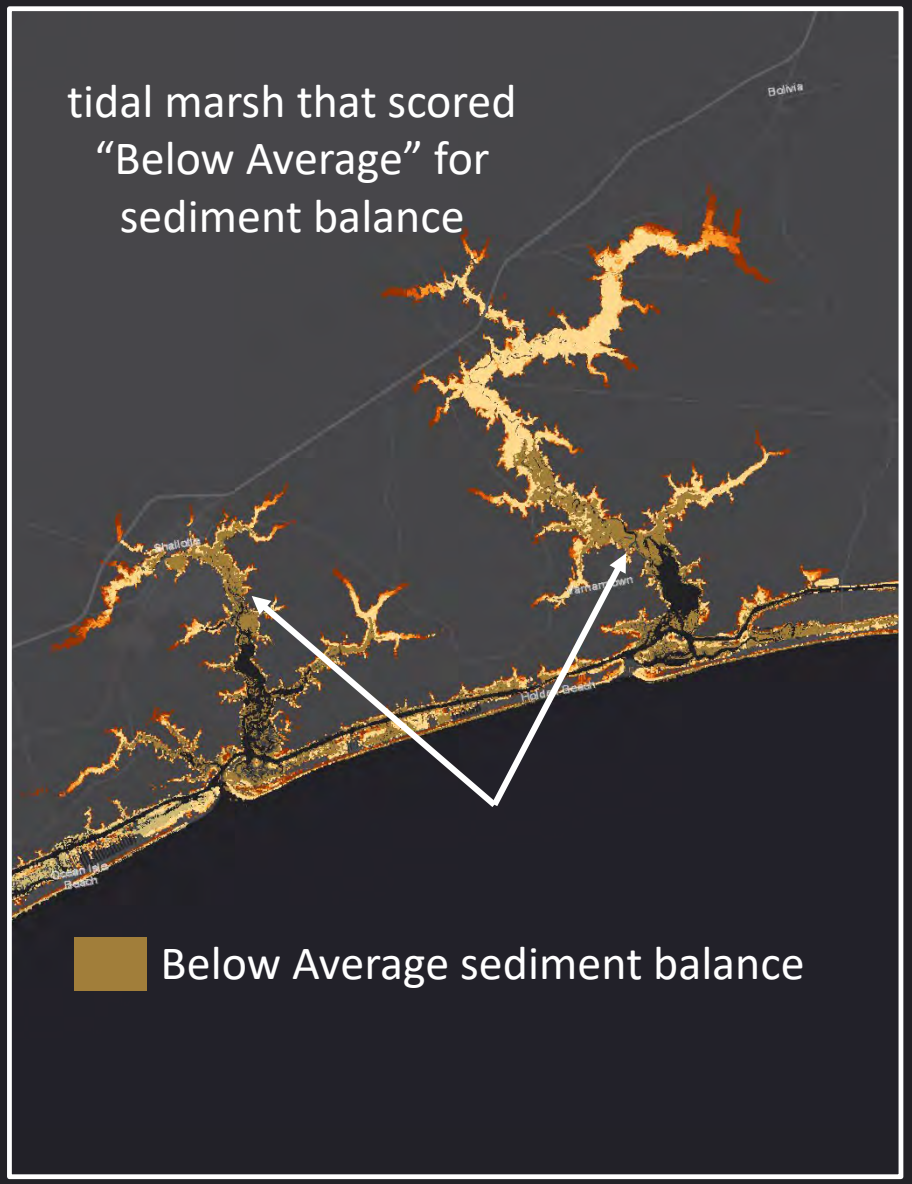
Using the Results

Restoration: Poor Water Quality



North Landing River

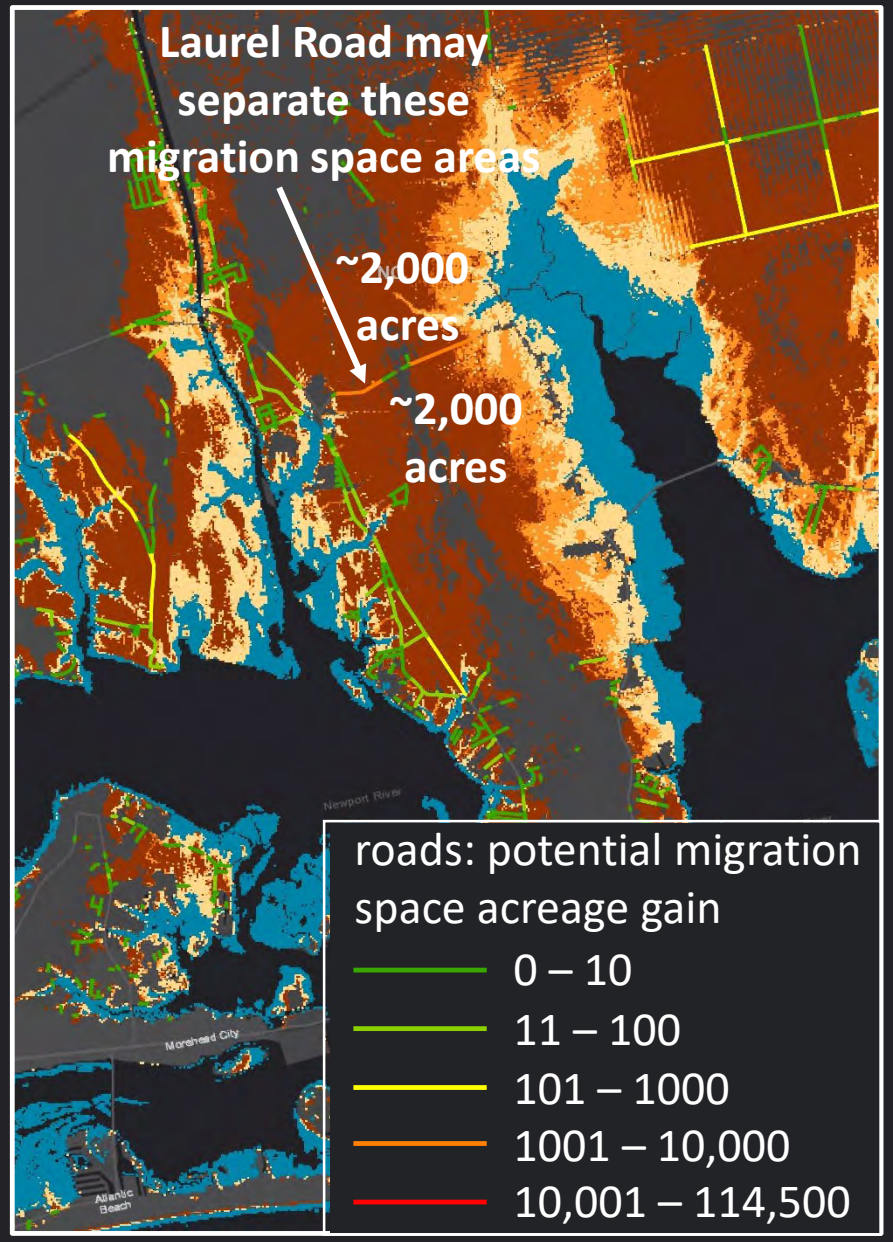
Restoration: Low Sediment



Shallotte & Varnamtown

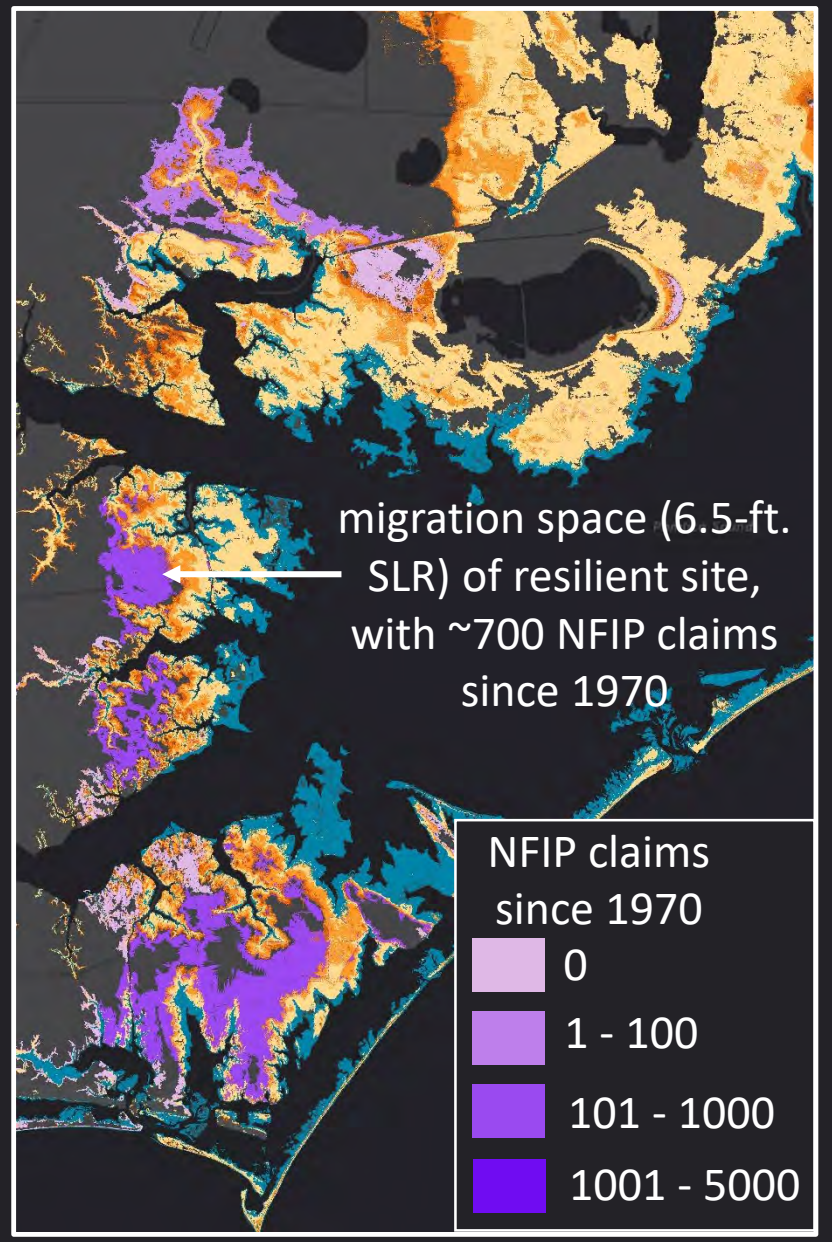
Using the Results

Fragmenting Roads



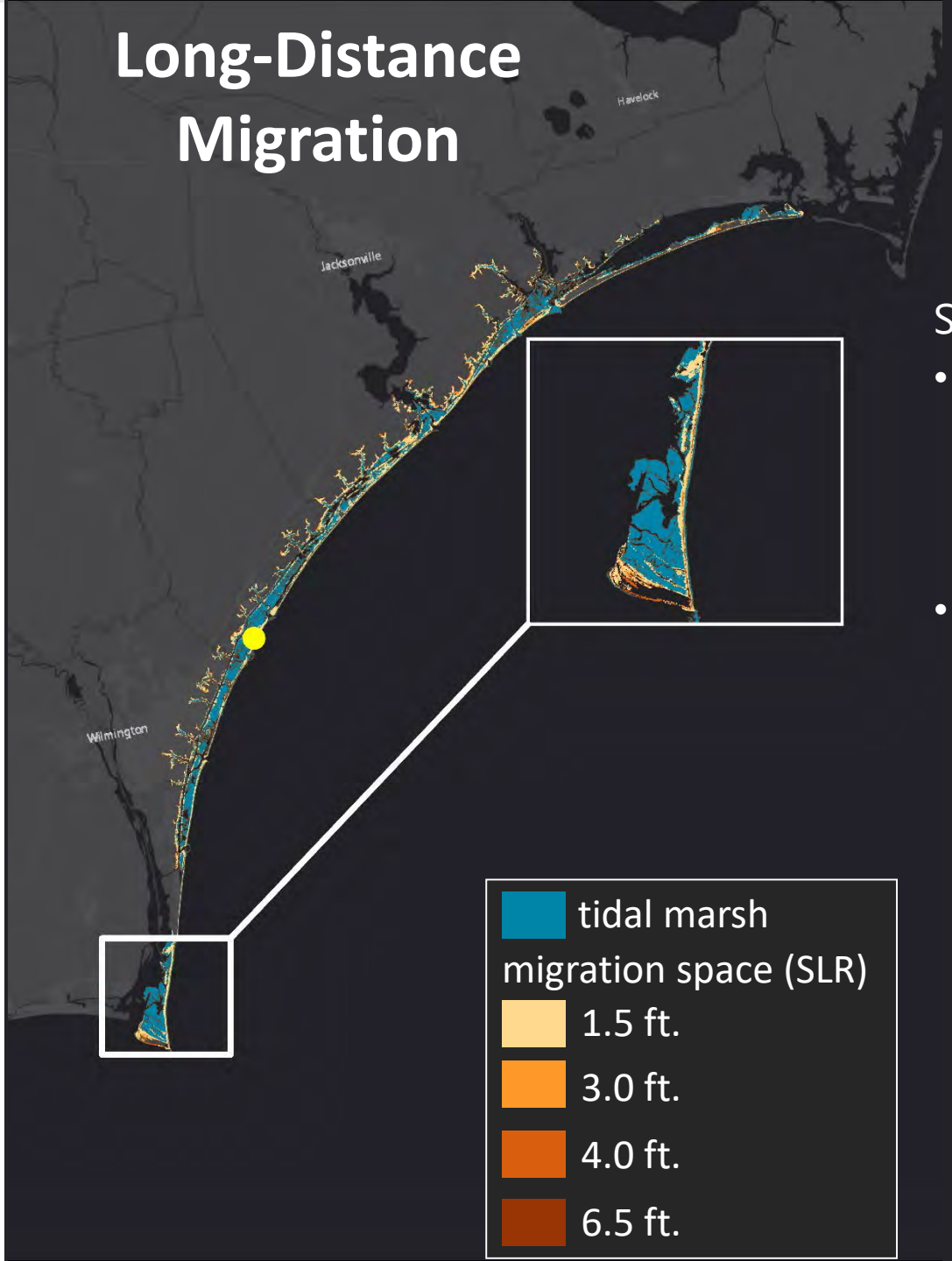
Newport River area

Repeat Flooding



Pamlico Sound

Using the Results



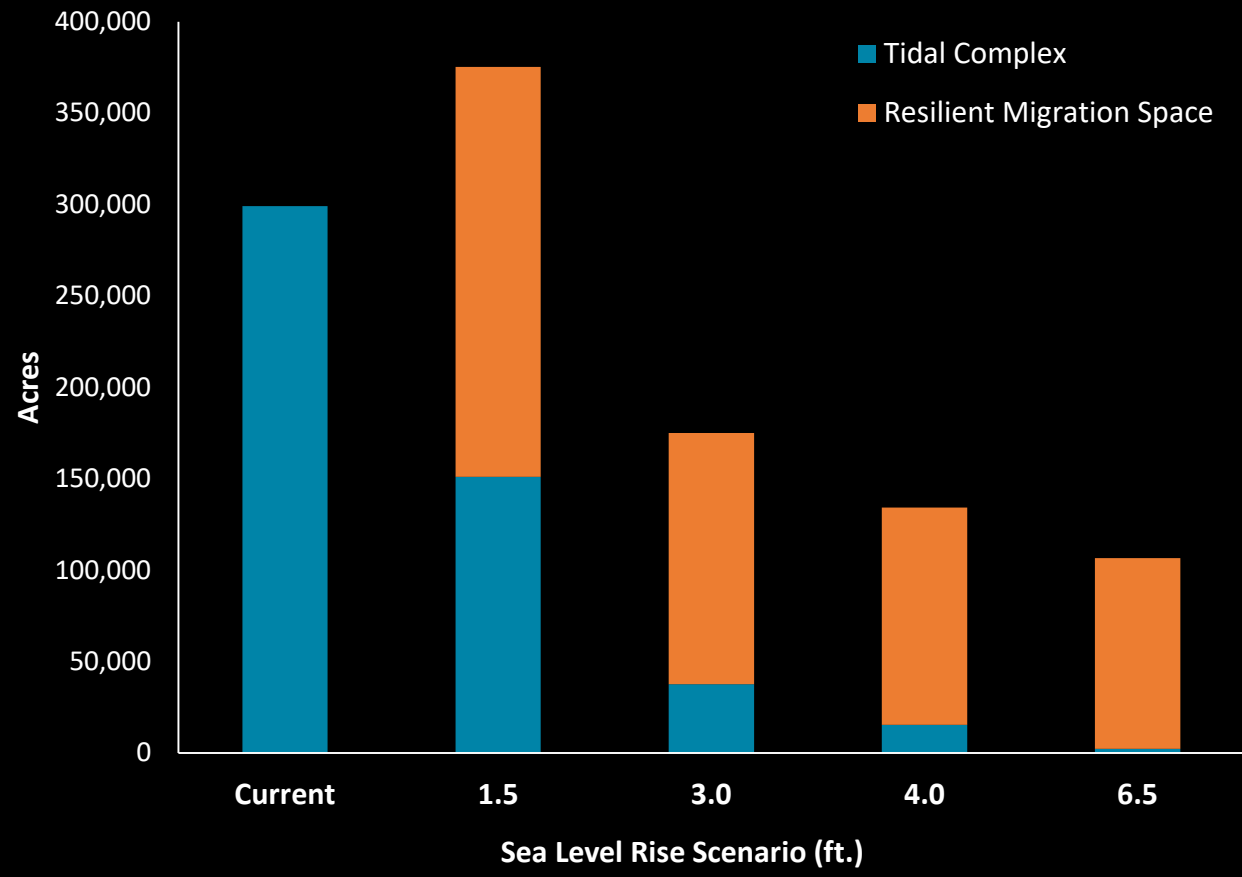
Single tidal complex (site) in blue.

- 1.5-feet of SLR - 8,219 acres of migration space; largest unit is 557 acres at southern end of complex (see inset).
- 6.5-feet of SLR – largest unit is 684 acres at the northern end of complex, near Camp Lejeune.

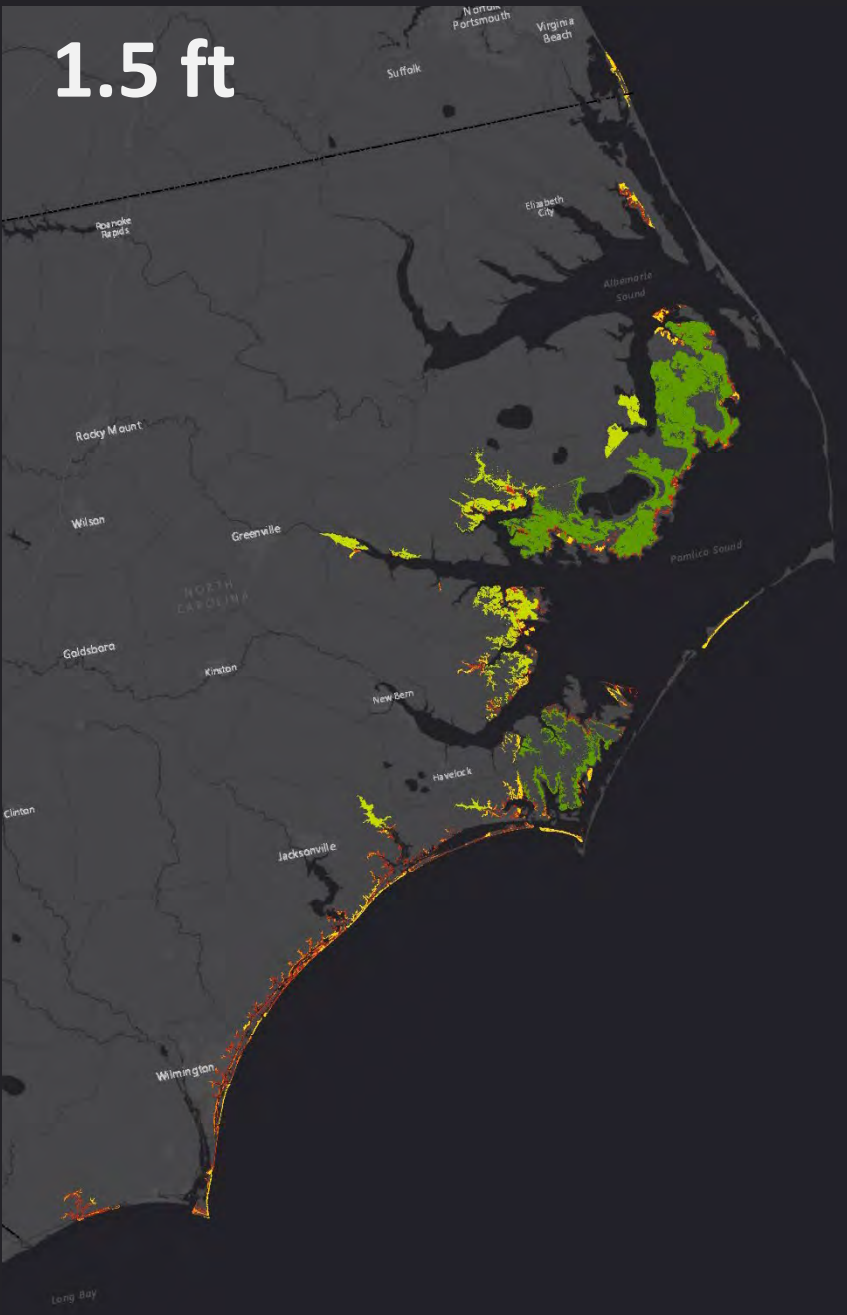
North Carolina: Future Marsh Estimates*

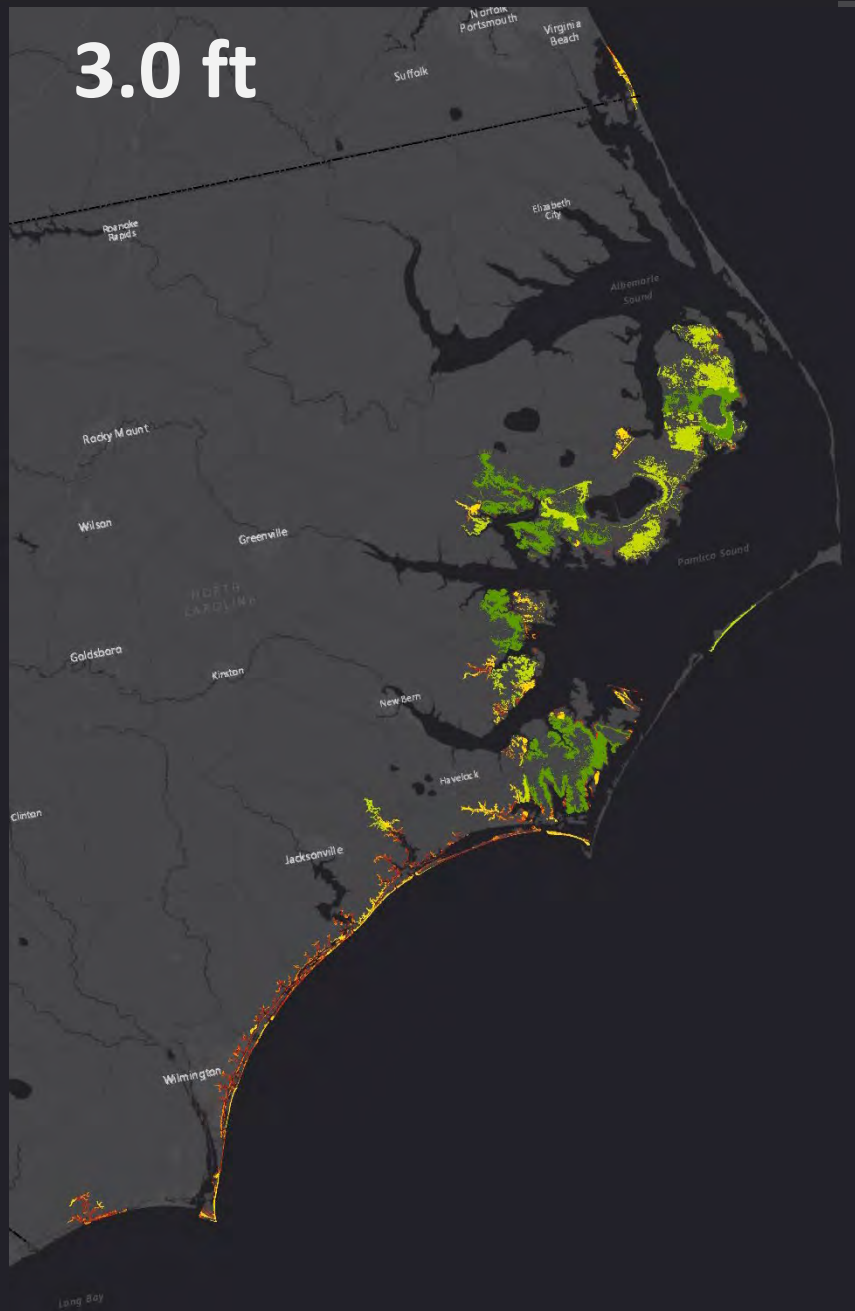
**based only on spatial analysis*

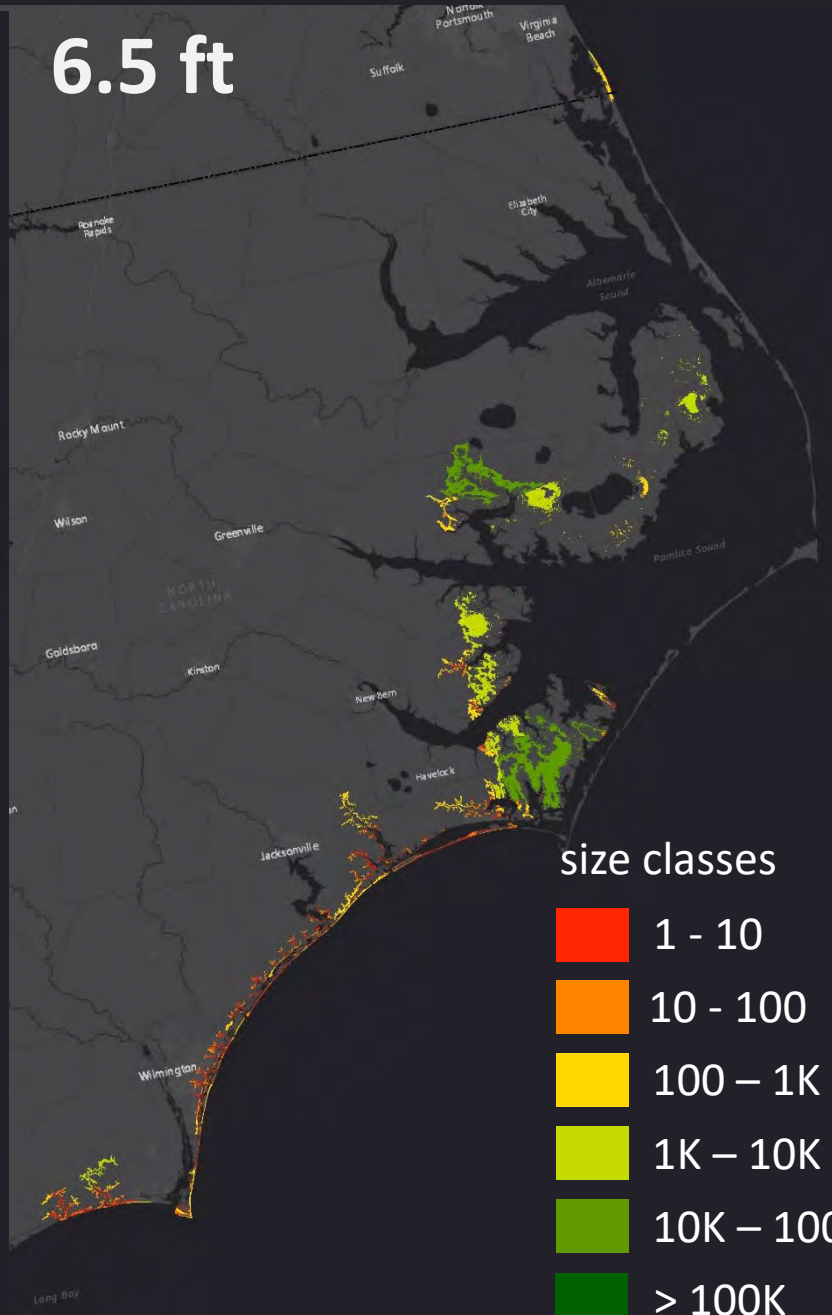
Incorporating the migration space of resilient sites



Migration Space of Resilient Sites



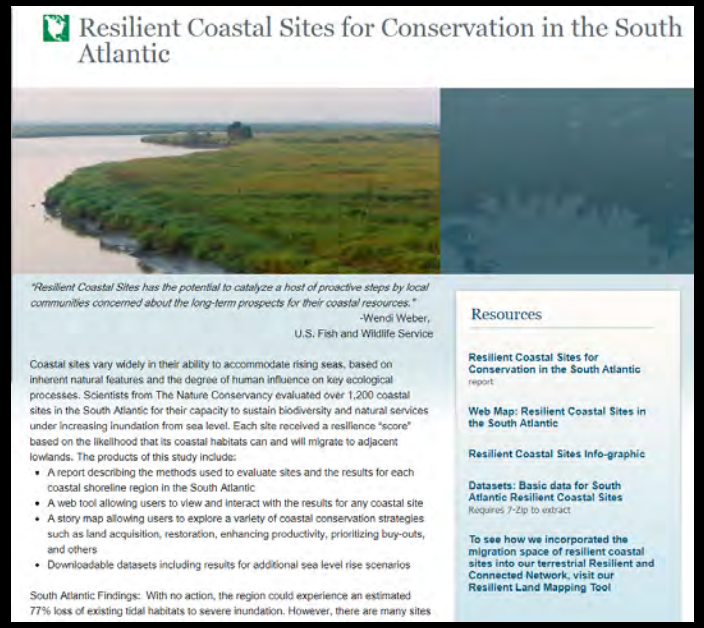




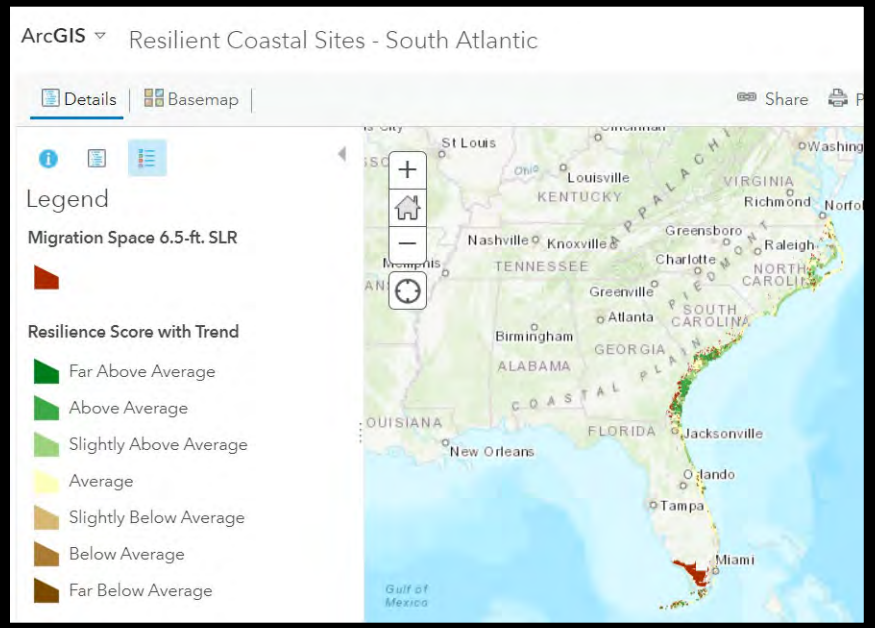
Products

-Website
-Report
-Data Downloads
-Web Map
-Strategies Story Map

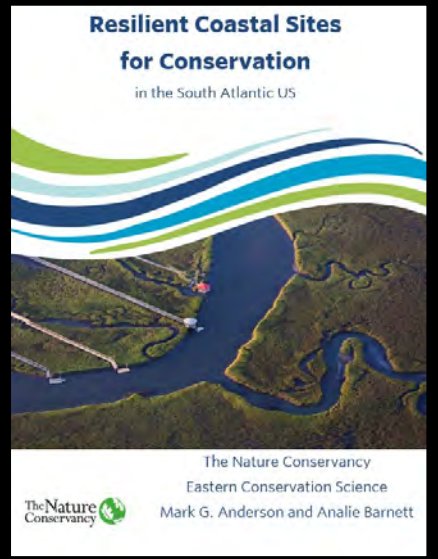
https://www.nature.org/resilientcoasts



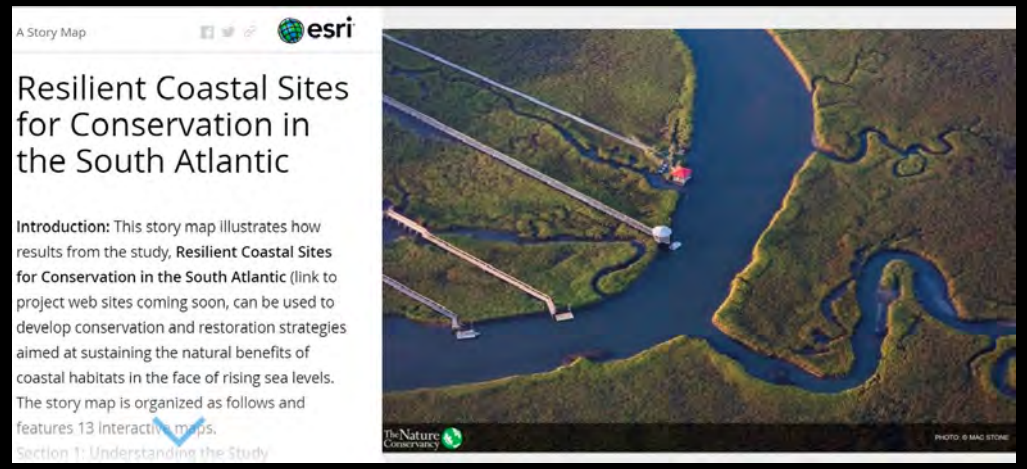
Website: Access project products, including datasets



Web Map: interact with the datasets and zoom to areas of interest.

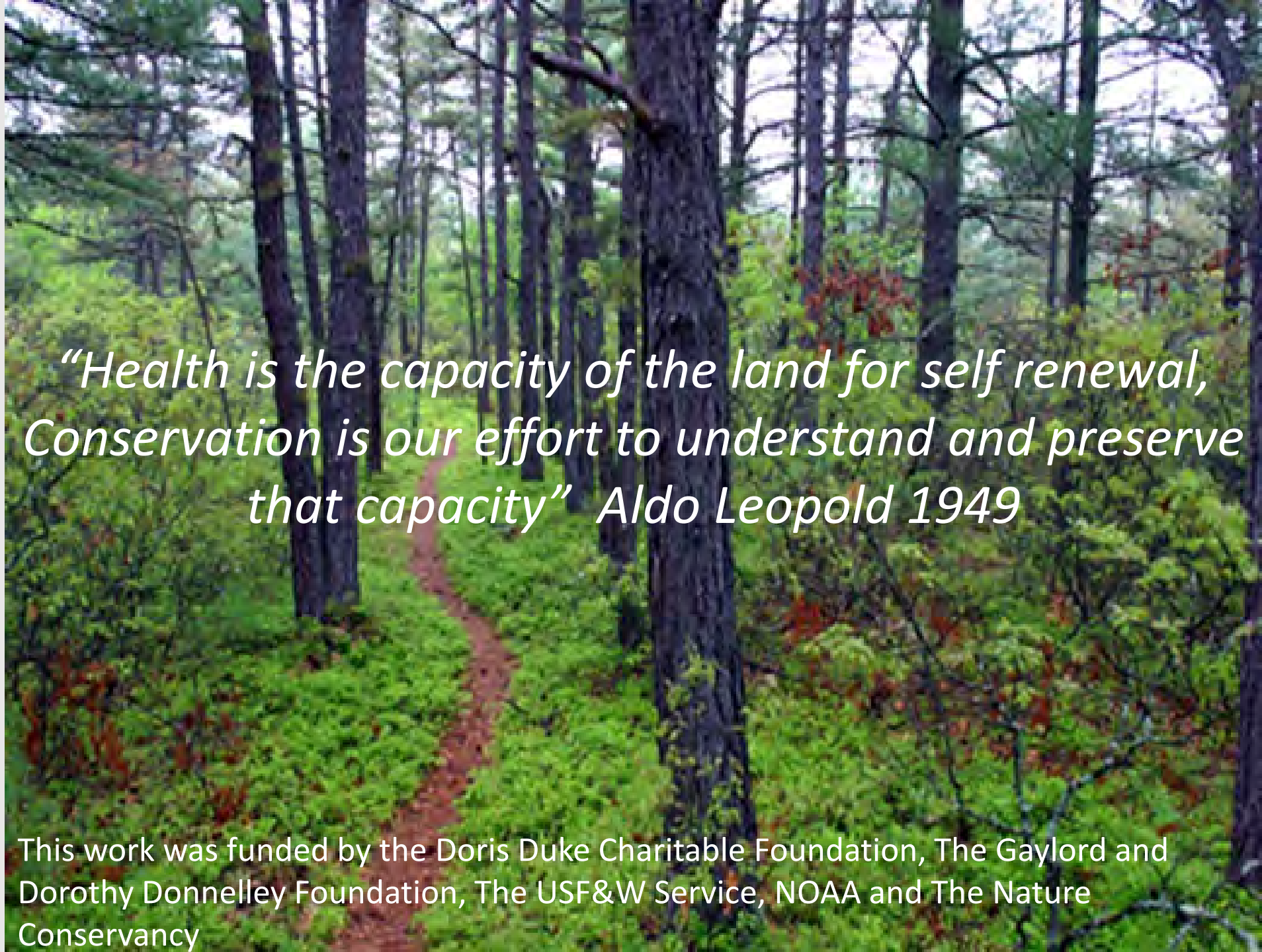


Report: read about the concepts of site resilience, how we measured it, and how to interpret the results.



Strategies Story Map (*DRAFT*): See examples of how the results could be used. http://arcg.is/0Wym1L

Thank You!



This work was funded by the Doris Duke Charitable Foundation, The Gaylord and Dorothy Donnelley Foundation, The USF&W Service, NOAA and The Nature Conservancy

NC Sentinel Site Cooperative

LAND: DUNES AND BEACHES

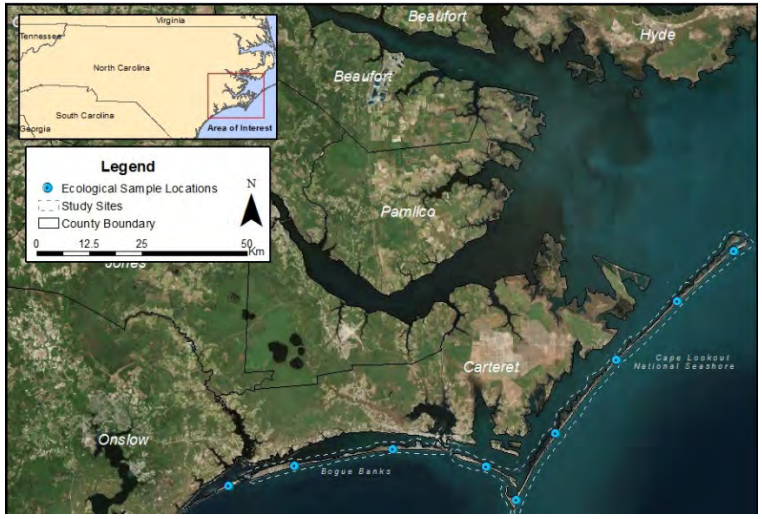
The Coastal Recovery from Storms Tool (CReST): A Model for Assessing the Impact of Sea Level Rise on Natural and Managed Beaches and Dunes

PIs: Peter Ruggiero, Sally Hacker, Laura Moore

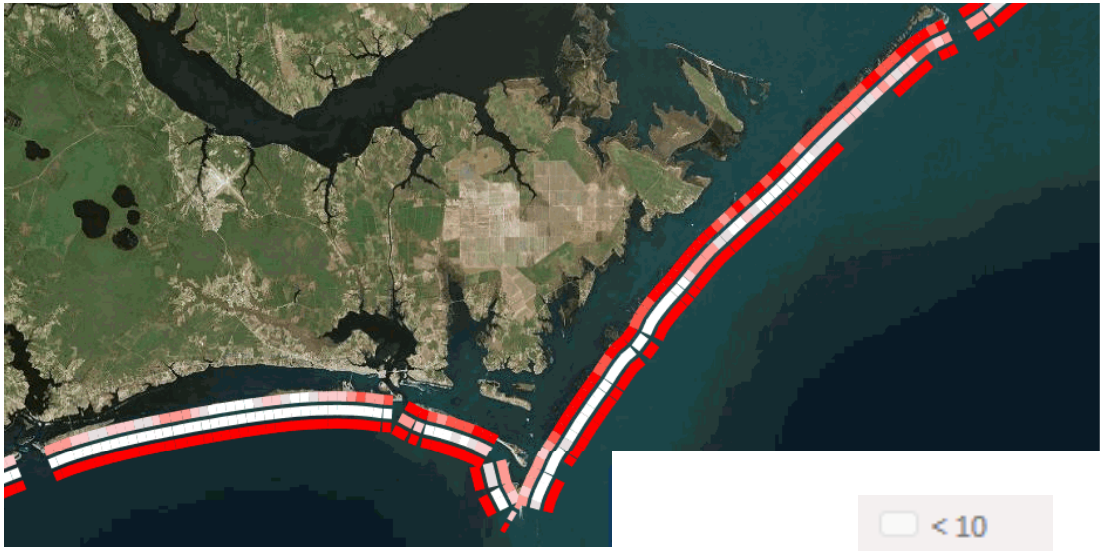
Given by: Michael Itzkin

Students/Postdocs/Technicians: Reuben Biel, Nick Cohn, Evan Goldstein, Paige Hovenga, Michael Itzkin, Katya Jay, Rebecca Mostow, Elsemarie Mullins, Ian Reeves, Orencio Duran Vinent, John Stepanek, Hannah Lawrence

Study Site: NCSSC outer coast



Project Motivation:
Storm Impact Assessments do not account for Dune Evolution



Probability (%) of inundation (inner), overwash (middle), and collision (outer) during a CAT3 hurricane

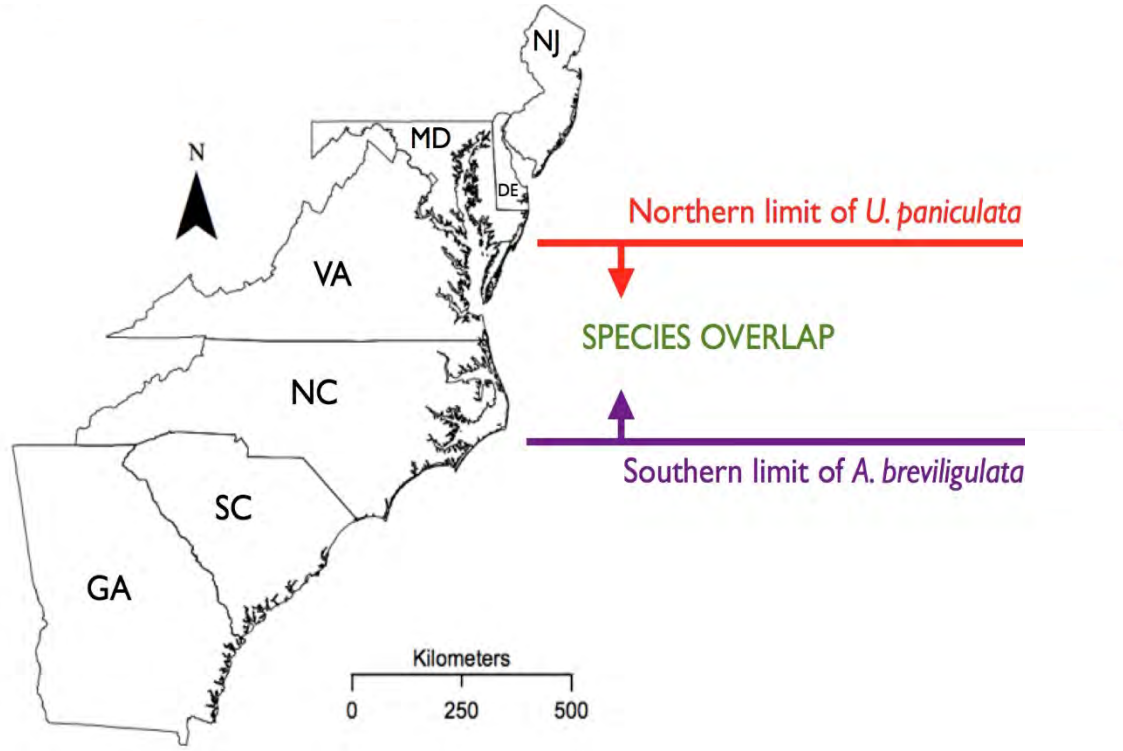
USGS
science for a changing world

Project Motivation:
Dune Shape and Growth Patterns Impact Coastal Protection Services

*(Left panel) Photo of **dune erosion and damage to infrastructure** along Bogue Banks following Hurricane Floyd in 1999.*

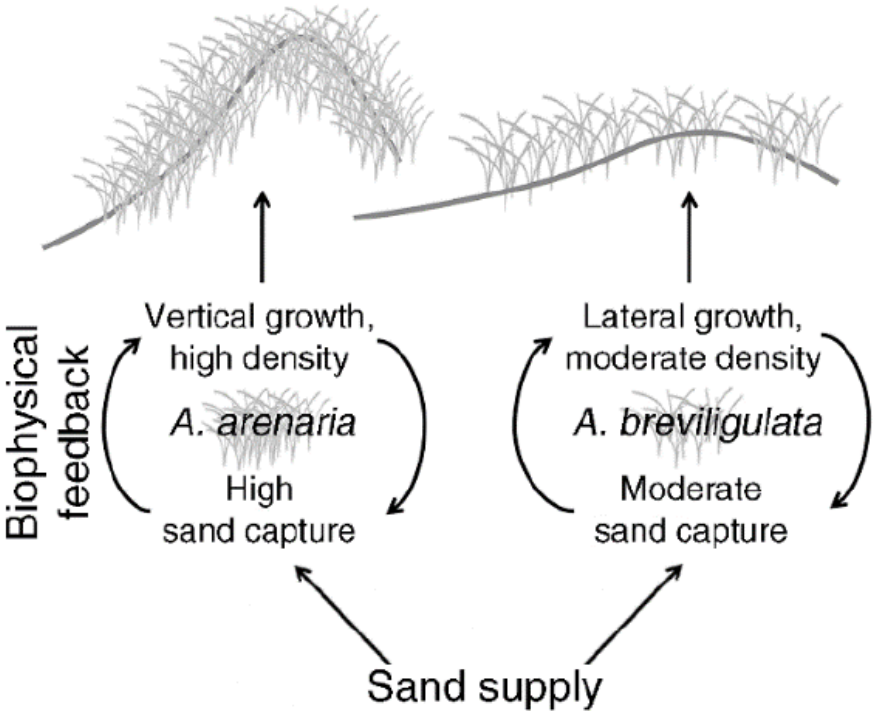
*(Right panel) Photo of **'incipient' dune** erosion and **only minor damage to infrastructure** on a sand nourished beach following Hurricane Irene in 2011 (photos courtesy Greg 'Rudi' Rudolph).*

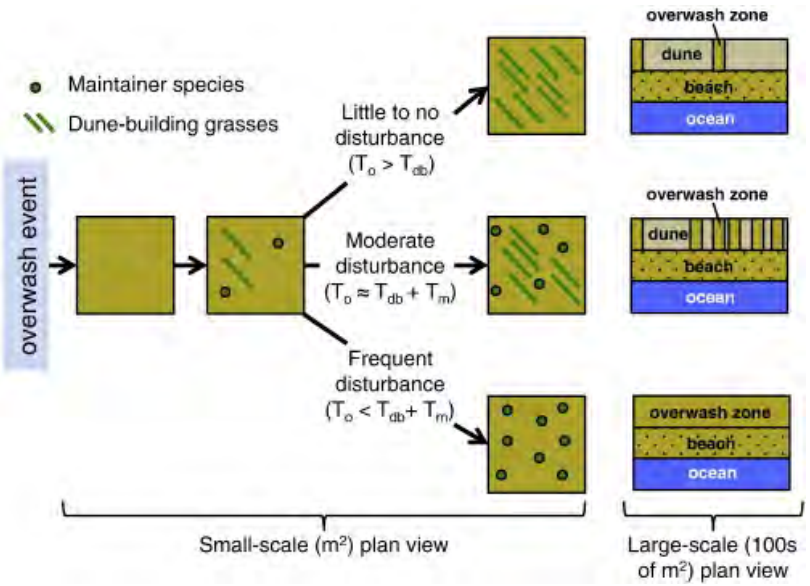
Project Motivation:
Gradient in Grass Species May Influence Dune Evolution



Map of the Mid-Atlantic coast. Red arrows highlight published southern limits of *Ammophila breviligulata*. Green arrows highlight the northern limits of *Uniola paniculata*.

Role of vegetation in dune shape





after Zarnetske et al. 2012 and Wolner et al., 2013

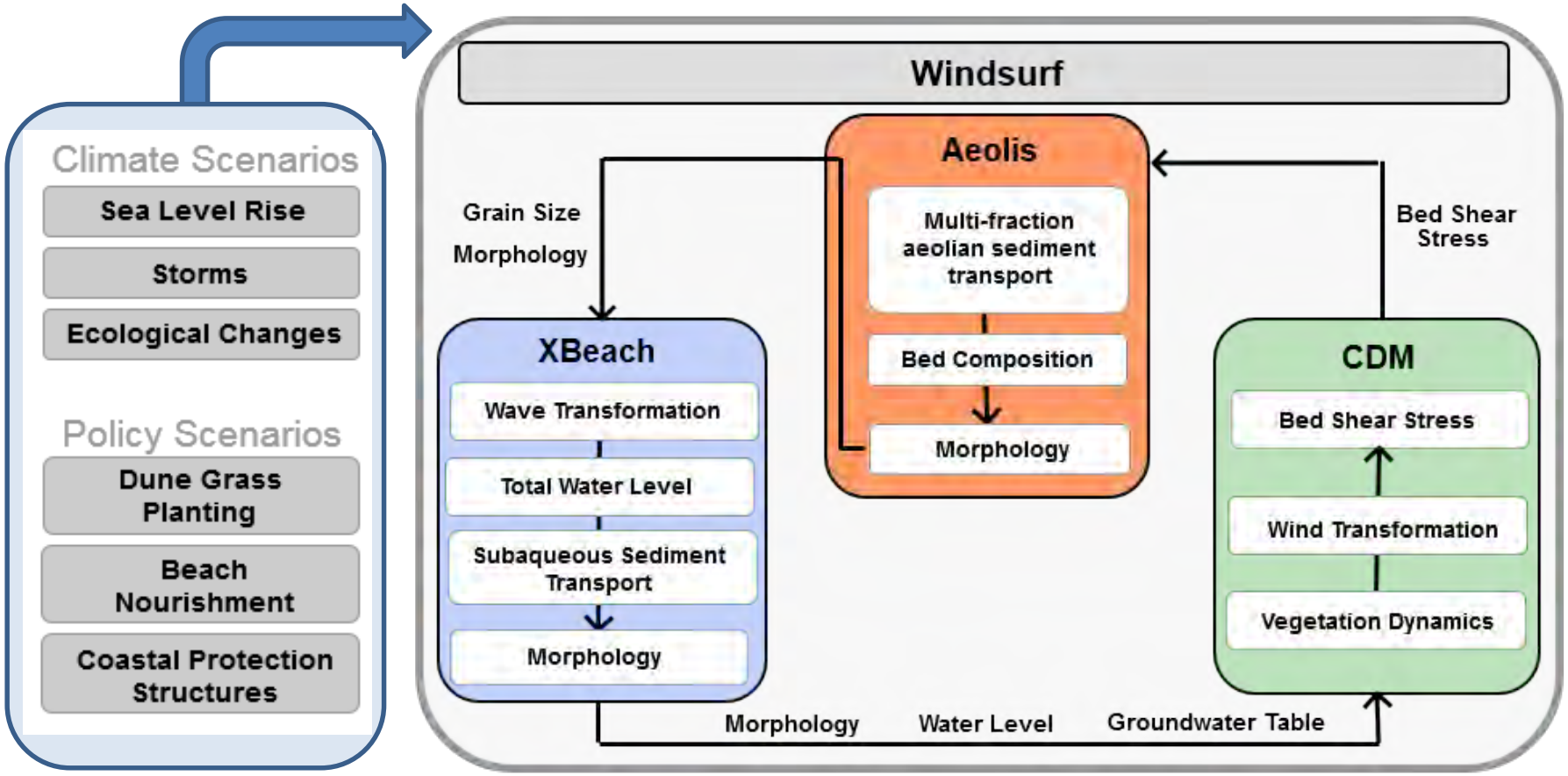
Project Objectives:

- **Develop the Coastal Recovery from Storms Tool (CReST)**, which will integrate an emerging understanding of biophysical processes by explicitly coupling SLR, sediment transport processes, and the dynamics of dune-building beach grasses to assess the time and space scales of beach and dune evolution in both natural and managed systems.

- **Apply CReST to Cape Lookout National Seashore (CReST-CALO)**, to estimate recovery and vulnerability to future storm events under a variety of SLR, storm change, and management scenarios.

- **Apply CReST to Bogue Banks (CReST-BB)**, in particular examining the impact of extensive beach nourishment programs on dune recovery following storms as well as under various SLR, storm change, and management scenarios.

What is CReST?



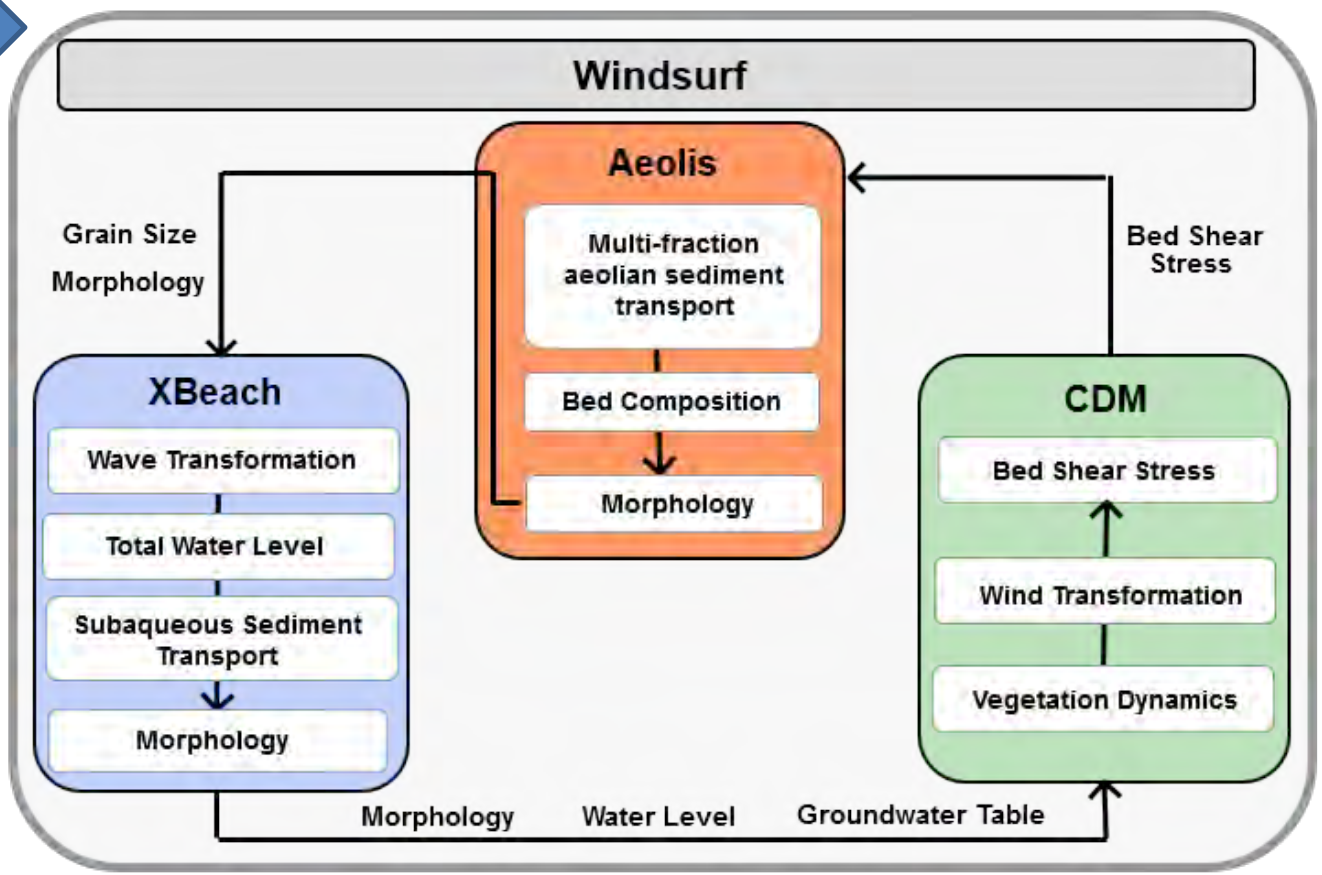
Roelvink et al., 2009

de Vries et al., 2014
Hoonhout and de Vries, 2016

Durán and Moore, 2013

The Coastal Recovery from Storms Tool (CReST)

What is CReST?

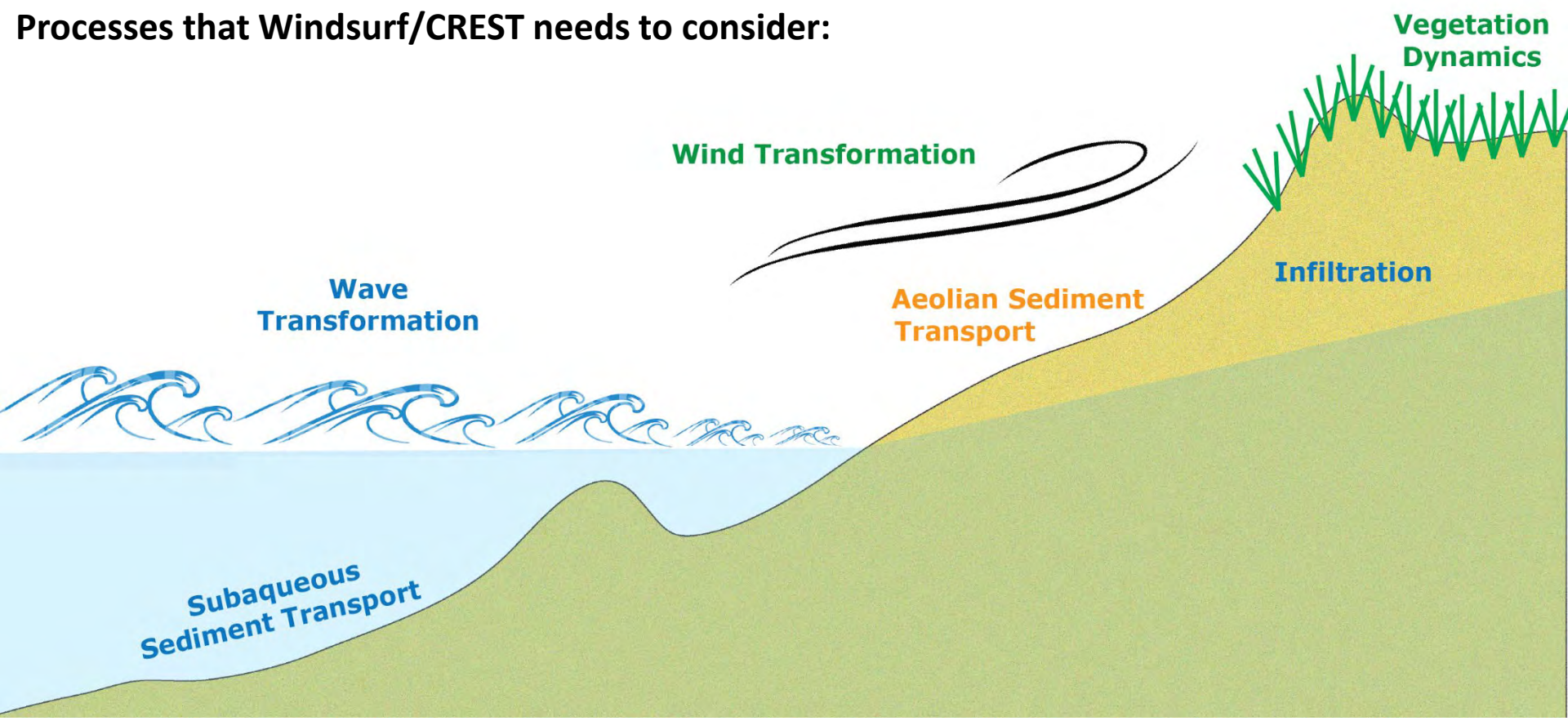


Roelvink et al., 2009

de Vries et al., 2014
Hoonhout and de Vries, 2016

Durán and Moore, 2013

Processes that Windsurf/CREST needs to consider:



Factors Controlling Beach and Dune Recovery/Growth

Environmental Conditions

- Wind
- Water levels (tides, storm surge, runup)
- Waves/storm frequency
- Groundwater table
- Climate

Physical/Ecological Factors

- Sediment Supply and Type
- Vegetation
- Tectonics
- Engineering Structures
- Management actions

The Coastal Recovery from Storms Tool (CReST)

Data/Information needed to develop CReST:

Beach and dune geomorphology

Dune ecology

Policy Options

Environmental forcing

Climate change

Coastal Management Issues within NCSSC:

- October 26 2015 Stakeholders Workshop (Pivers Island, NC)
- October 21 2016 Stakeholders Workshop (Pivers Island, NC)

- Ongoing meetings/discussions with NCSSC staff
- Ongoing meetings/discussions with CALO administration/staff
- Ongoing meetings/discussions with Rudi Rudolph (Carteret County, NC)

Coastal Management Issues within NCSSC:

BB: Beach nourishment, grass planting, and sand fencing to protect against flooding and erosion

SHB: Pony habitat, bird habitat, shoreline erosion

SCB: Bird habitat, turtle habitat, infrastructure, driving impacts

NCB: Bird habitat, turtle habitat, erosion near cabins – possible plantings/fencing, driving impacts

NCSSC: climate change impacts on coastal hazards/coastal ecosystems

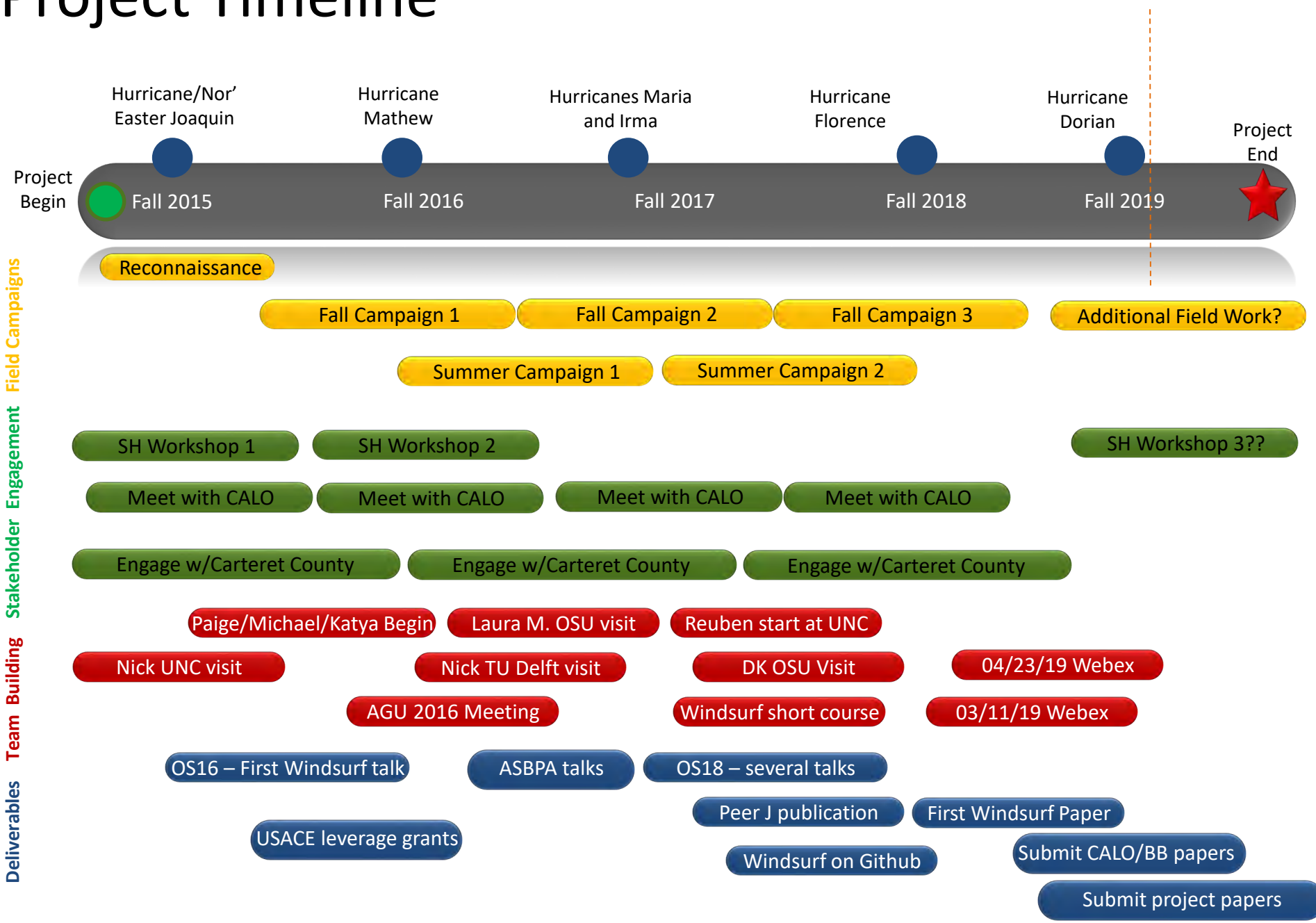
Data needed to develop CReST:

- October 2015 Field Campaign (recon trip due to Joaquin)
- October 2016 Field Campaign
- June 2017 Field Campaign (leveraged)
- October 2017 Field Campaign
- June 2018 Field Campaign (leveraged)*
- October 2018 Field Campaign*

Beach and dune geomorphology

Dune ecology

Project Timeline



NC EESLR: Completed Papers

1. Goldstein, E., Mullins, E.V., Biel, R.G., Brown, J.K., Hacker, S.D., Jay, K.R., Mostow, R.S., Ruggiero, P., and Zinnert, J.C., 2018. Literature-based latitudinal distribution and possible range shifts of two US east coast dune grass species (Uniola paniculata and Ammophila breviligulata), PeerJ, doi: 10.7717/peerj.4932.

2. Goldstein, E. and Moore, L., 2018. A calibration workflow for coastal dune models, Shore and Beach, 86(3), 47-51.

3. Cohn, N., Hoonhout, B. Goldstein, E., de Vries, S. Moore, L., Duran, O.V., and Ruggiero, P., (2019). Exploring marine and aeolian controls on coastal foredune growth using a coupled numerical model, Journal of Marine Science and Engineering, *J. Mar. Sci. Eng.7*(1), 13; https://doi.org/10.3390/jmse7010013.

4. Ruggiero, P., Cohn, N., Hoonhout, B., Goldstein, E., de Vries, S., Moore, L., Hacker, S., Duran-Vinent, O., 2019. Simulating Dune Evolution on Managed Coastlines:Exploring Management Options with the Coastal Recovery from Storms Tool (CReST), Shore and Beach, 87(2), 36-43.

5. Hovenga, P.A., Ruggiero, P., Cohn, N., Jay, K.R., Hacker, S.D., Itzkin, M., and Moore, L., 2019. Drivers of dune evolution in Cape Lookout National Seashore, NC., Proceedings Coastal Sediments 2019, St. Pete Beach, FL.

6. Hacker, S. D., Jay, K. R., Cohn, N., Goldstein, E. B., Hovenga, P. A., Itzkin, M., Moore, L. J., Mostow, R. S., E. V. Mullins, Ruggiero, P. (2019). Species-specific functional morphology of four US Atlantic Coast dune grasses : Biogeographic implications for dune shape and coastal protection. *Diversity*, *11*(5), 82, doi:10.3390/d11050082.

7. Itzkin et al., in review.

The Coastal Recovery from Storms Tool (CReST)

Influence of Dune Aspect Ratio and Storm Characteristics on Protective Services

Michael Itzkin, Laura J. Moore

UNC Chapel Hill, Department of Geological Sciences

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Shackleford Banks, NC
(*Photo: P. Hovenga, 2017*)

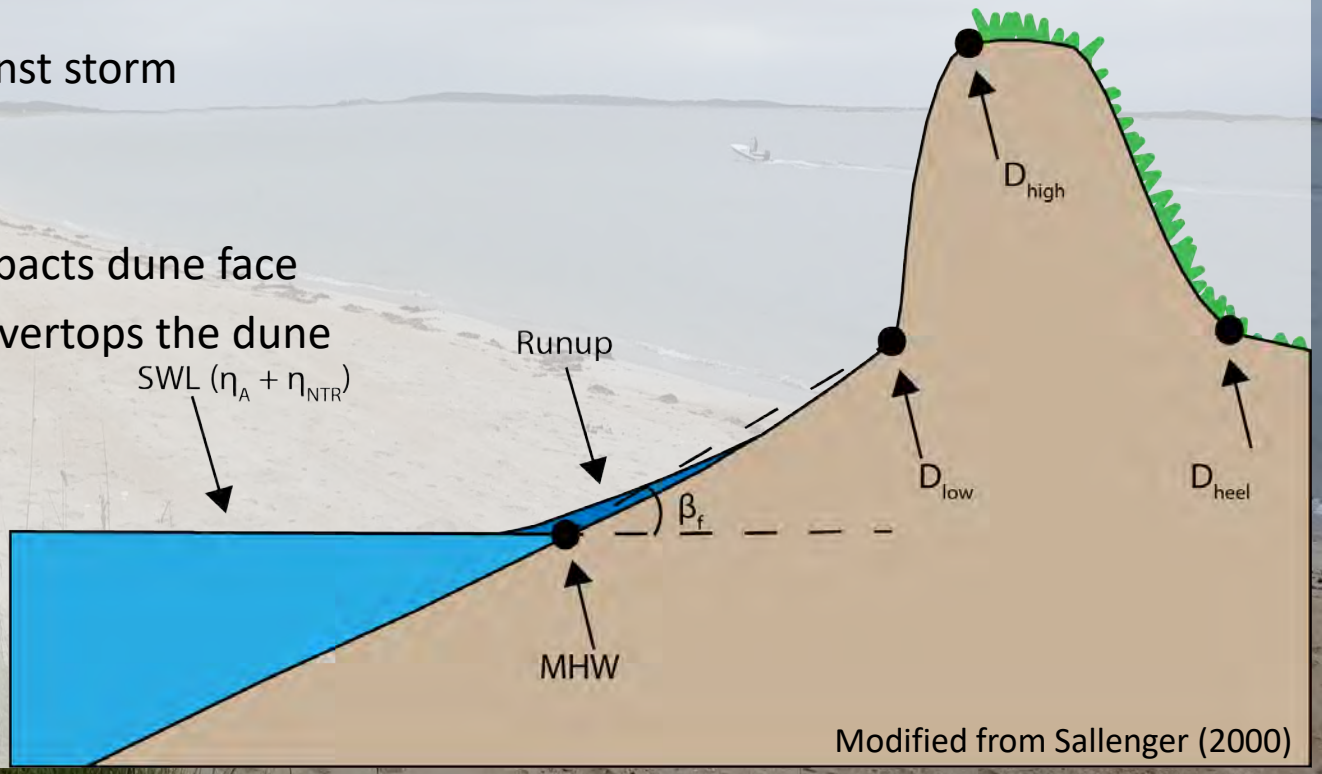
Influence of Dune Aspect Ratio and Storm Characteristics on Protective Services

Role of Foredunes in Protective Services

Foredunes:

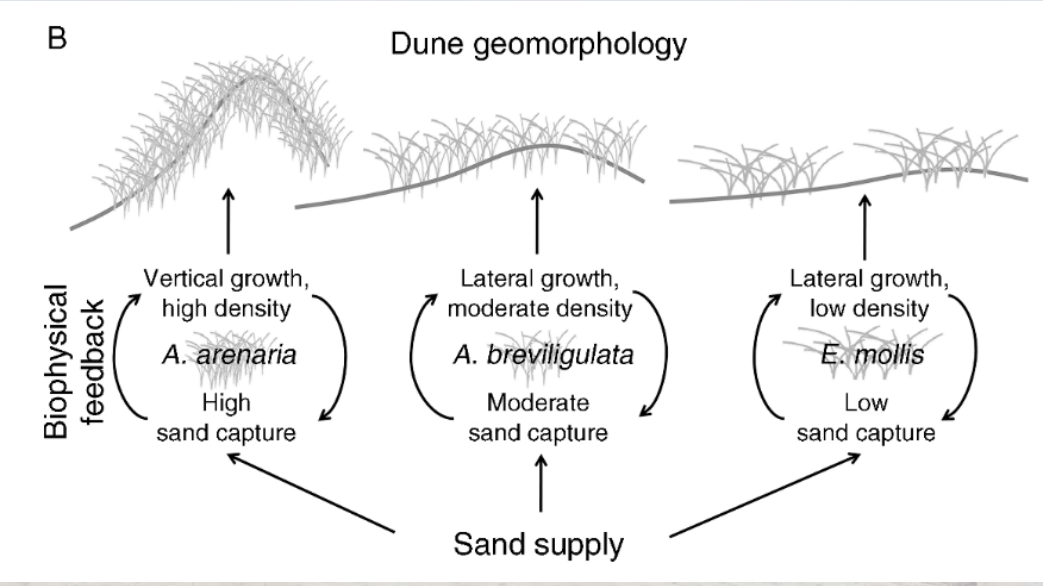
- Seaward most dune
- First line of defense against storm impacts

- Collision: Water level impacts dune face
- Overwash: Water level overtops the dune



Modified from Sallenger (2000)

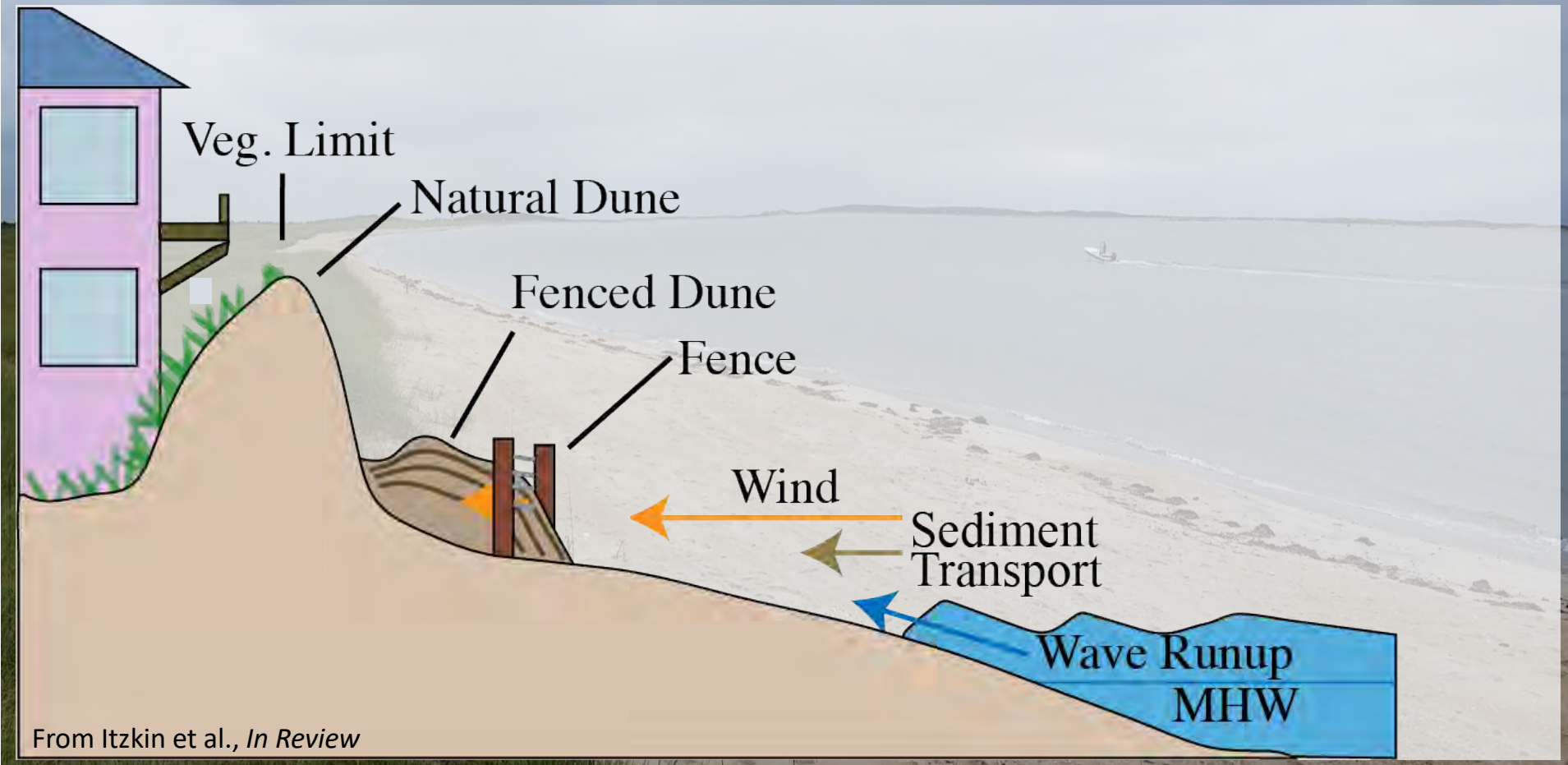
Natural Influences on Dune Aspect Ratio



Zarnetske et al. (2010), Figure 1

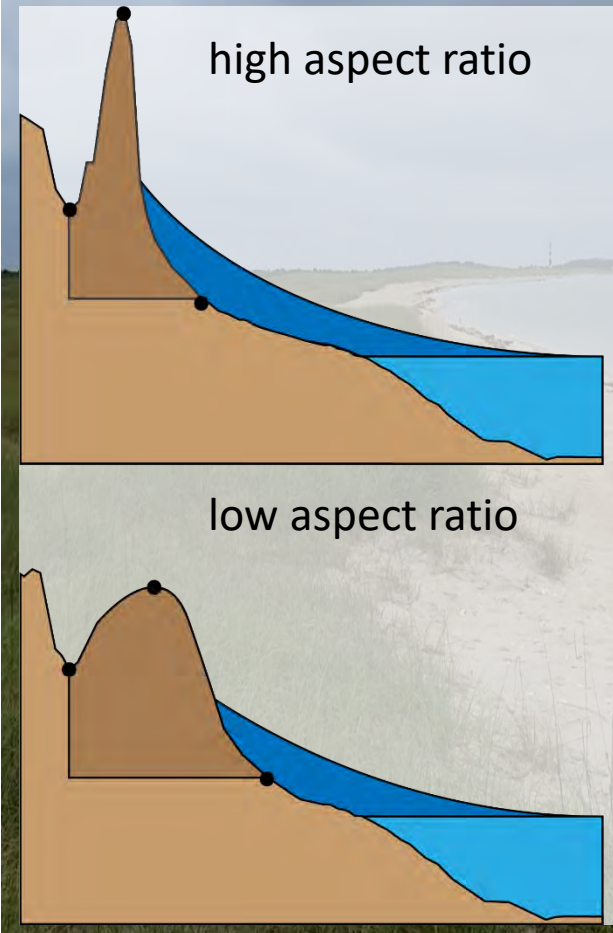
- Different grass species lead to different dune morphologies
  - Dune morphology mimics plant morphology
- Has implications for dune vulnerability
  - Ex. *A. Arenaria v. A. Breviligulata* in the PNW

Human Influences on Dune Aspect Ratio



From Itzkin et al., *In Review*

Questions



As a function of dune aspect ratio…

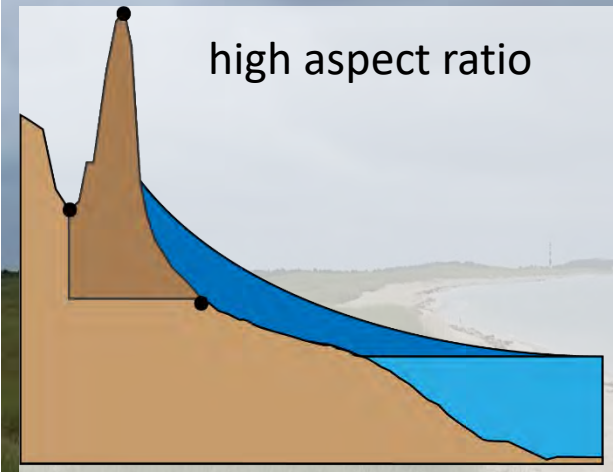
1. How does storm duration affect dune erosion?

2. How does altering total water level during a storm affect dune erosion?

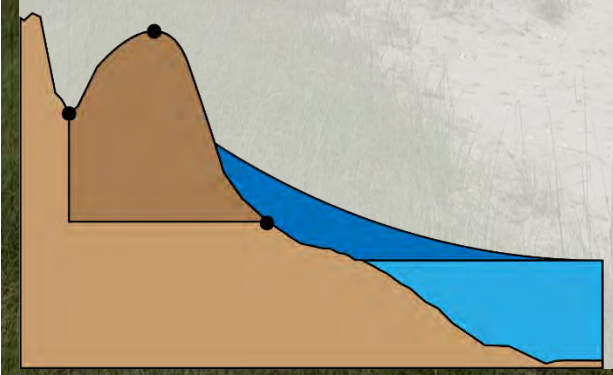
3. How does the configuration of dunes in the model influence erosion?

Questions

high aspect ratio



low aspect ratio



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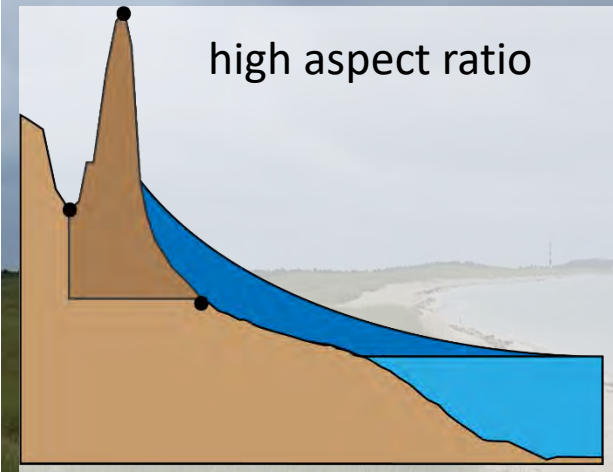
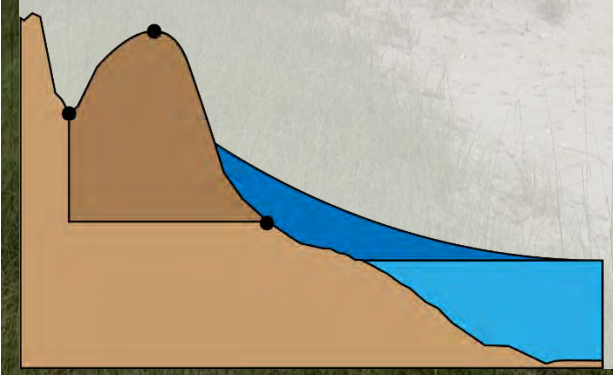


low aspect ratio



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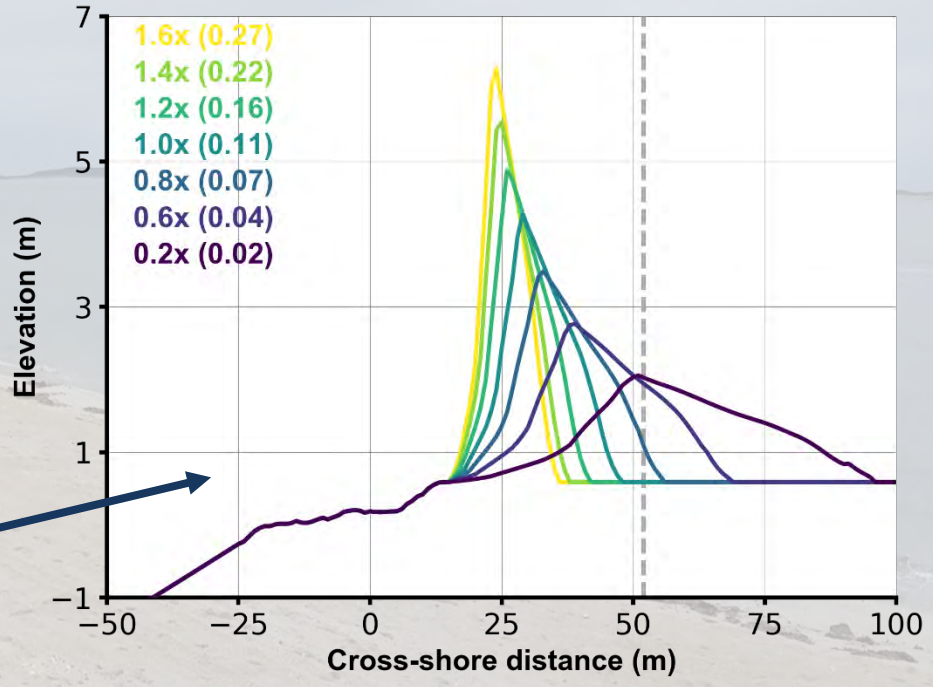
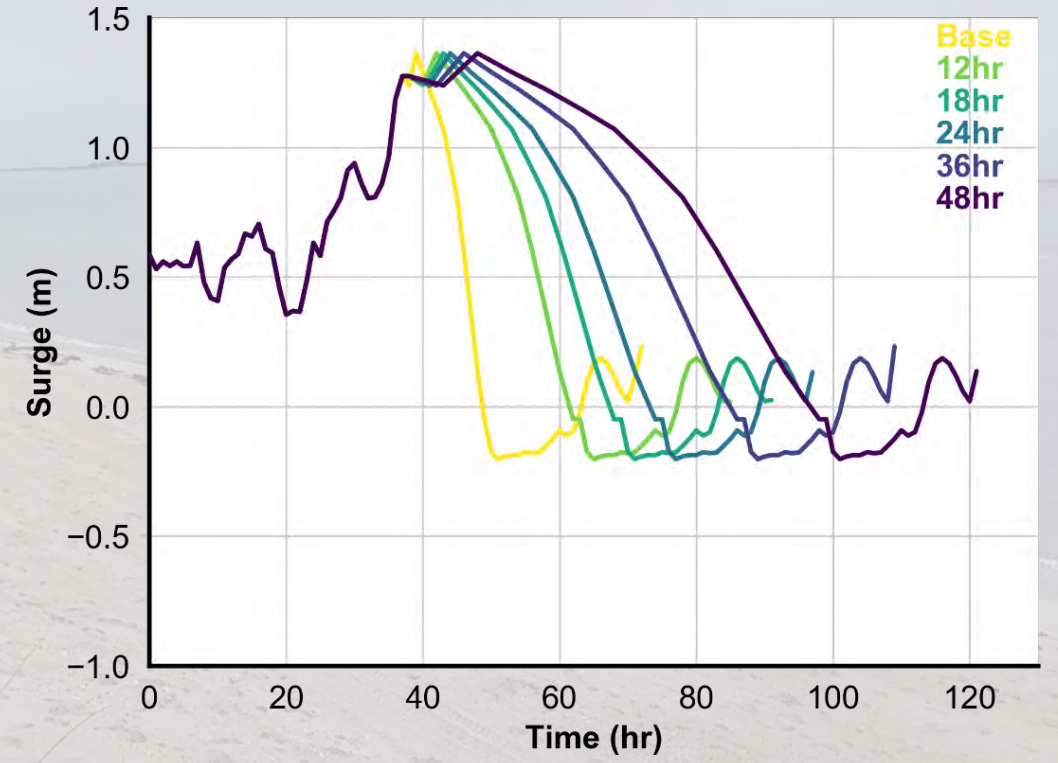
Synthesizing Dune Profiles

- Reference (1.0x) profile from Fort Macon, NC
- Stretched in 20% increments to ±60%
  - $Height_f = Height_0 * \left(1 - \frac{stretch}{100}\right)$
  - $Width_f = Width_0 / (1 - \frac{stretch}{100})$
- Dune volume between profiles is maintained within 3 m^3/m (~50 m^3/m)
- Three sets of profiles:
  - Toes aligned
  - Crest positions aligned
  - Heels aligned



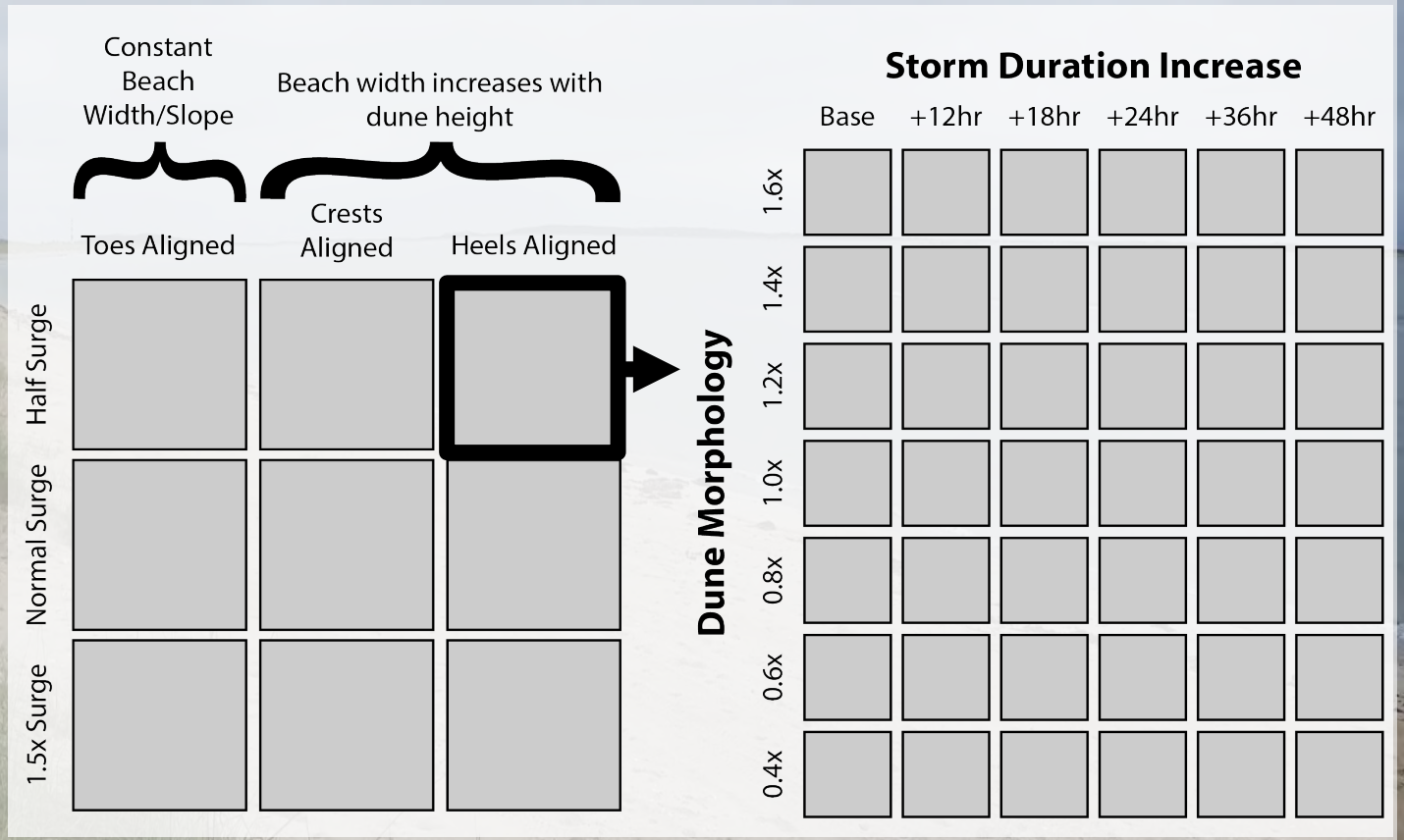
Synthesizing Storm Time Series

- Hurricane Matthew used as a reference storm
- Increased storm duration by stretching all hydrodynamic inputs relative to a 12 hr window centered on the timing of peak surge
- Storm duration increased by 12, 18, 24, 36, 48 hours
- Storm surge (NTR) multiplied by 0.5x, 1.0x, and 1.5x



Experimental Design

- XBeach
- 9 dune configuration and surge combinations
- 42 simulations for each of the above
- 378 simulations total

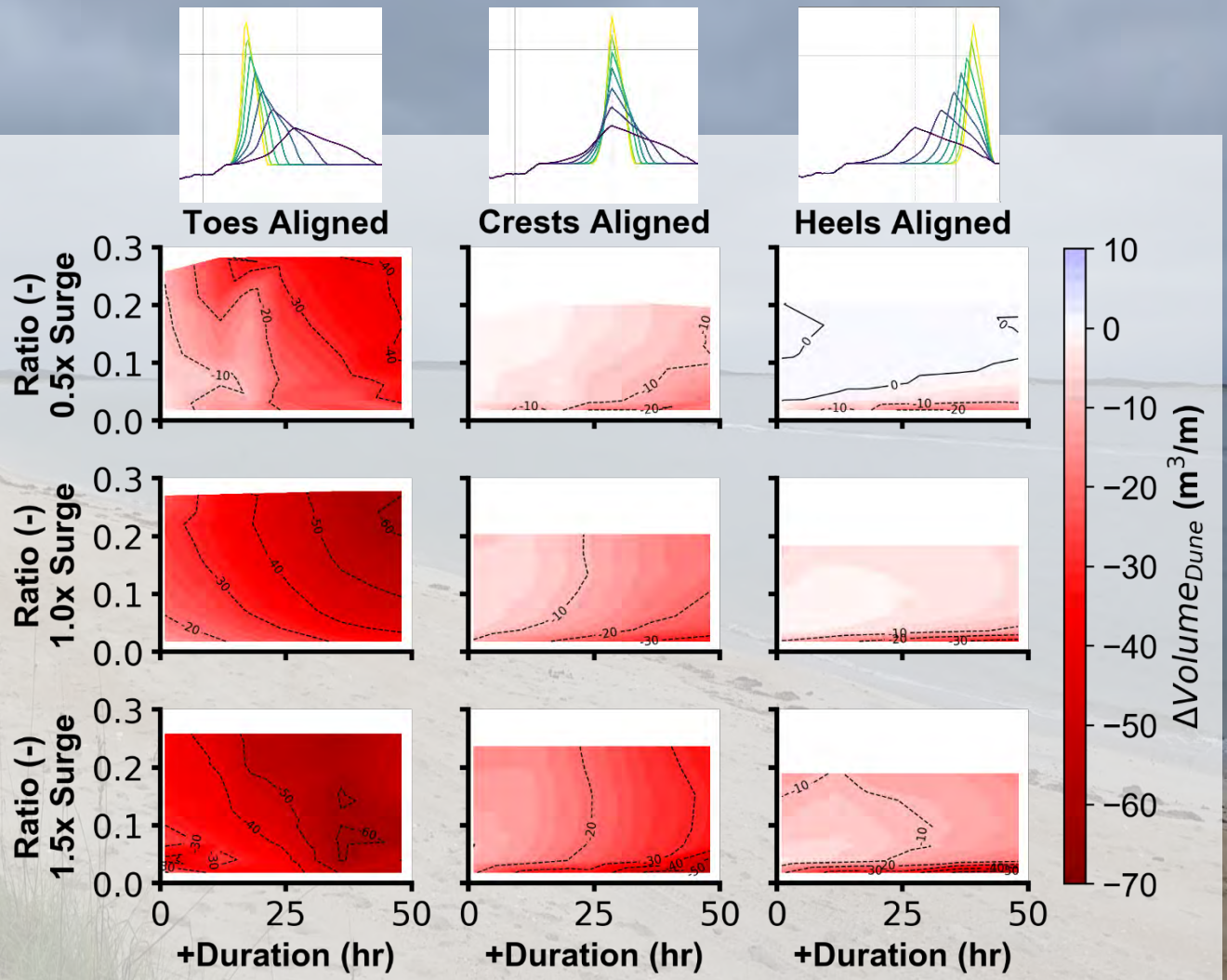


Results

High aspect ratio dunes:

- Lose more volume when toes are aligned
- More sensitive to storm duration when toes are aligned
- Trends reverse when crests/heels aligned

Beach morphology influences…



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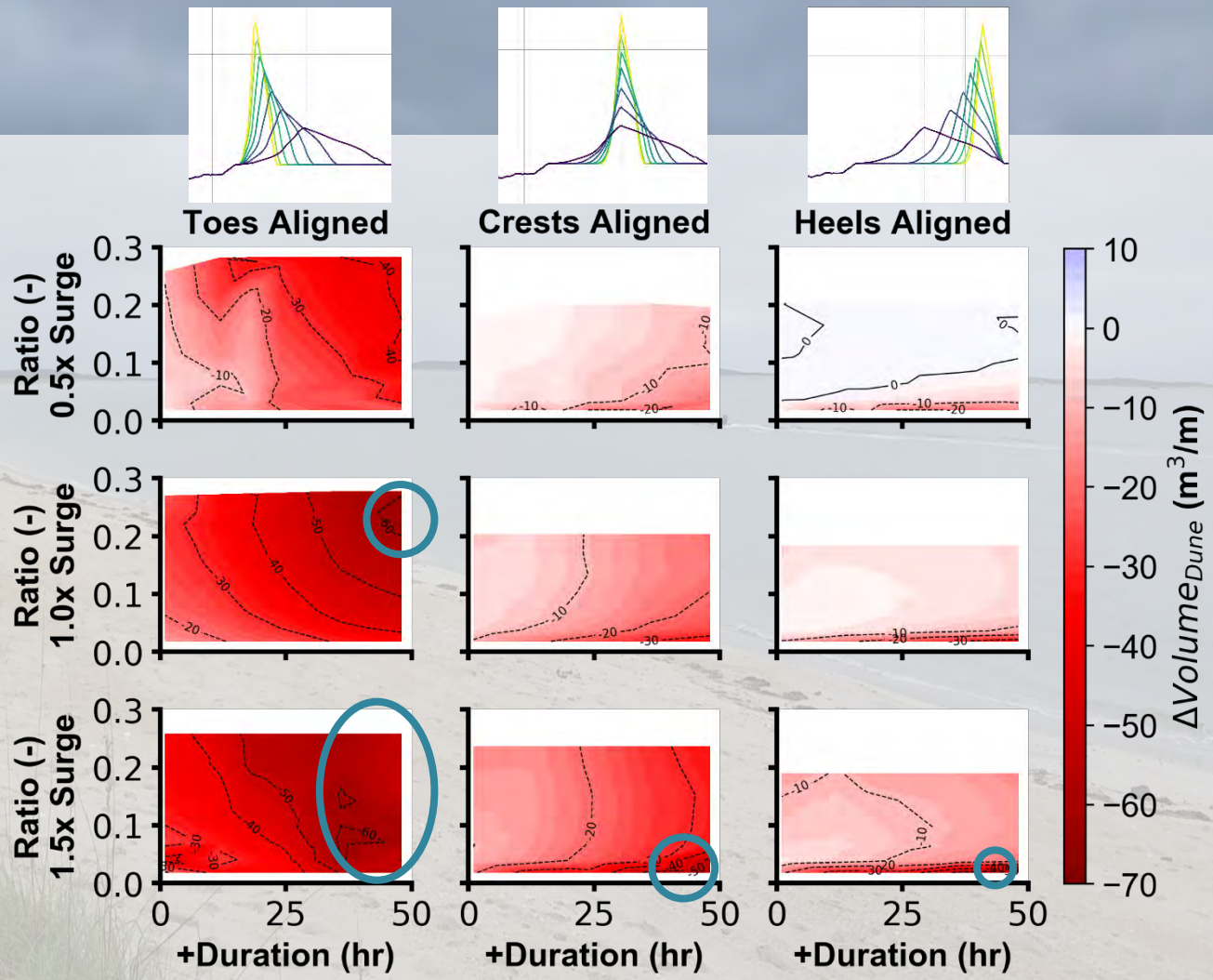


Results

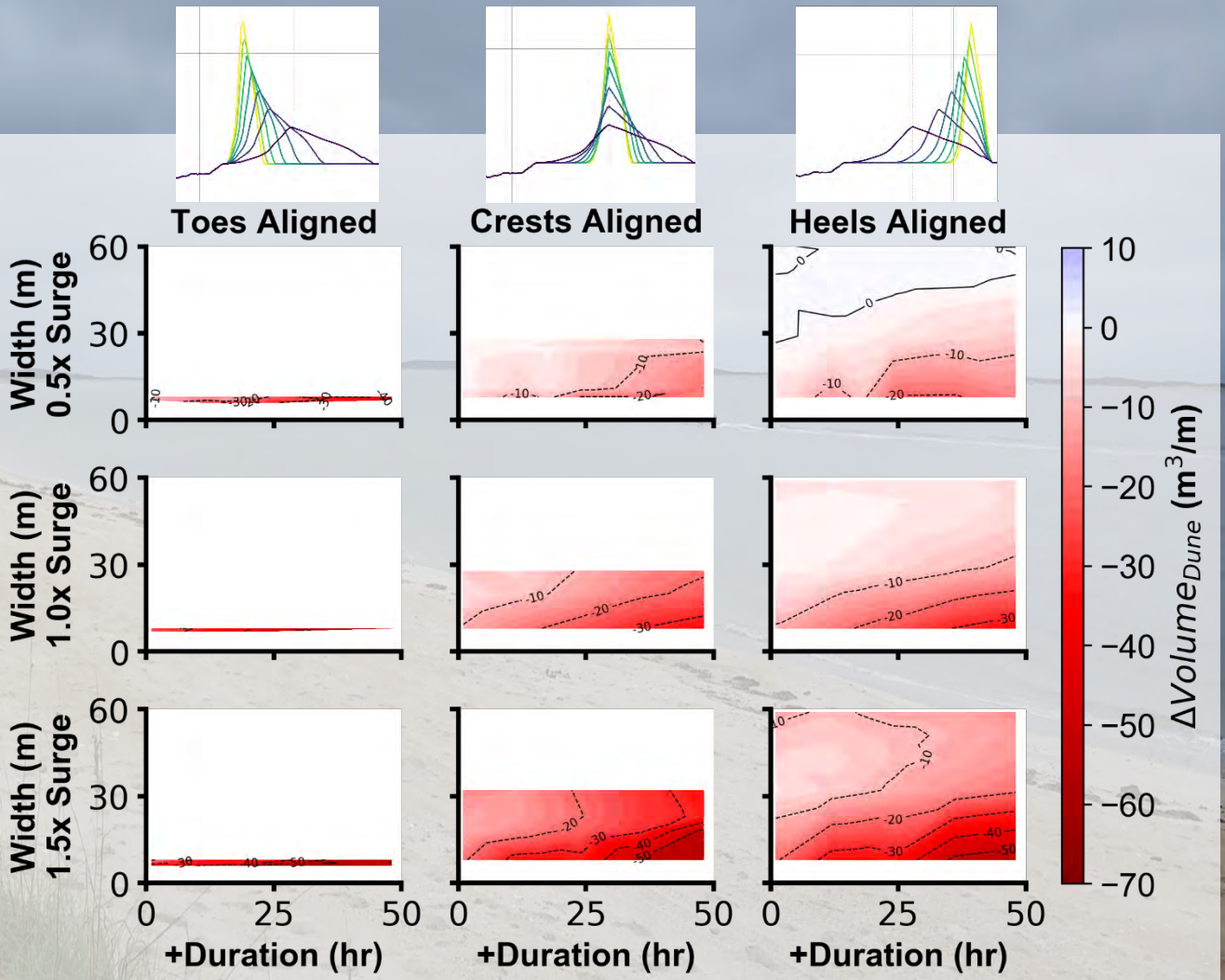
Toes aligned:

- Beach width is constant

Crests or heels aligned:

- Beach width increases with aspect ratio
- Volume loss decreases with beach width

Effect of duration decreases with beach width



Conclusions

As a function of dune shape..

1. How does storm duration affect dune erosion?
   - Low aspect ratio dunes are less sensitive to increases in duration than high aspect ratio dunes

2. How does altering total water level during a storm effect dune erosion?
   - Erosion increases with surge until the dune is either inundated (low H/W) or eroded through (high H/W)

3. How does the configuration of dunes in the model influence erosion?
   - Erosion increases significantly as dunes are positioned closer to the shoreline
   - Dunes are more sensitive to storm duration when the beach is narrower

Implications

Bogue Banks, NC (2018)

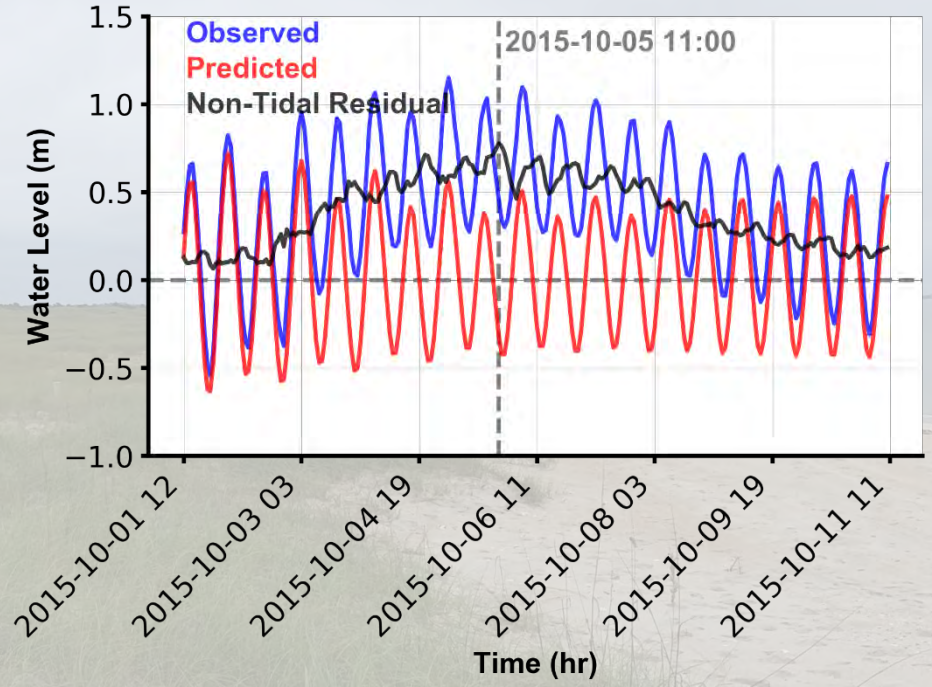
- Most ideal scenario would be a tall, wide dune with a wide beach
  - Wide beach offers most protection of the three
- A lower aspect ratio dune is more susceptible to overwash but less susceptible to volumetric erosion from collision, which occurs more frequently.
- Protective services may be enhanced by considering these effects relative to anticipated local storm characteristics when designing dune restoration projects.

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

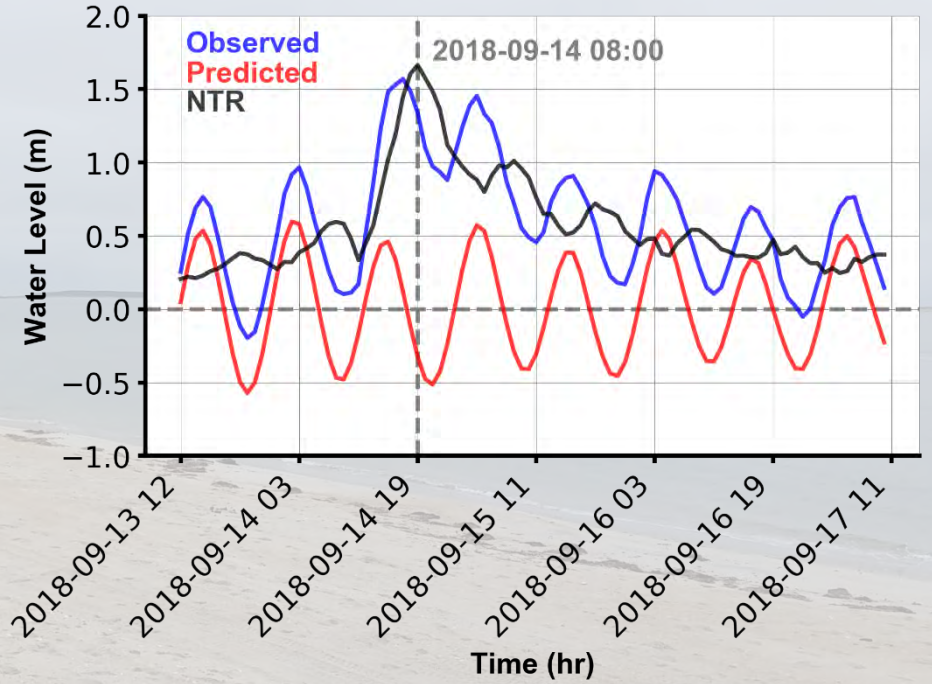
Shackleford Banks, NC
(*Photo: P. Hovenga, 2017*)

Observed Hydrographs

Tropical Storm Joaquin



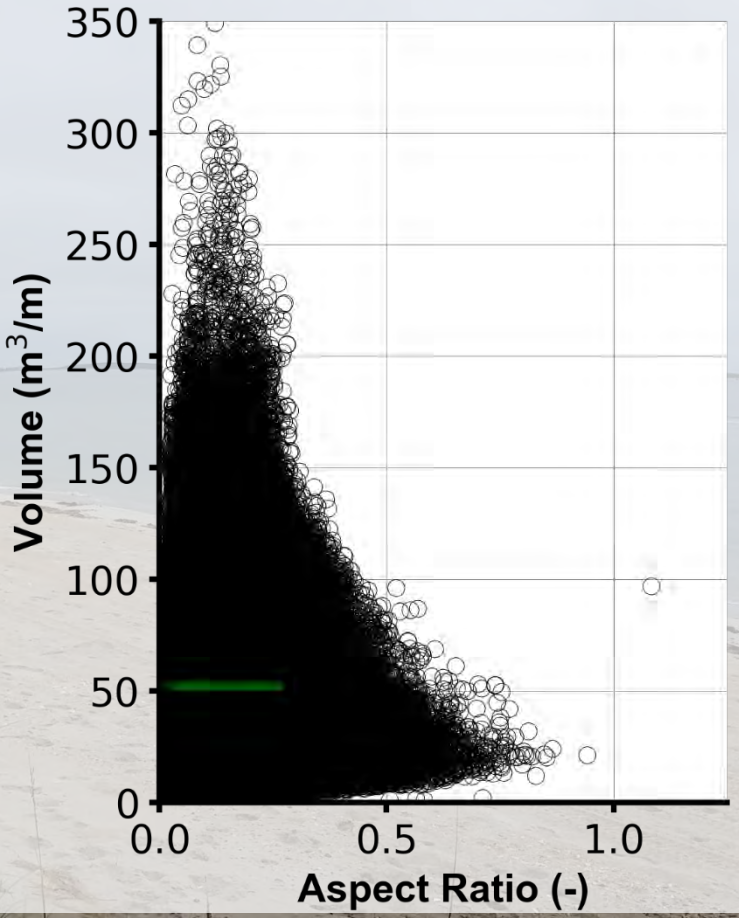
Hurricane Florence



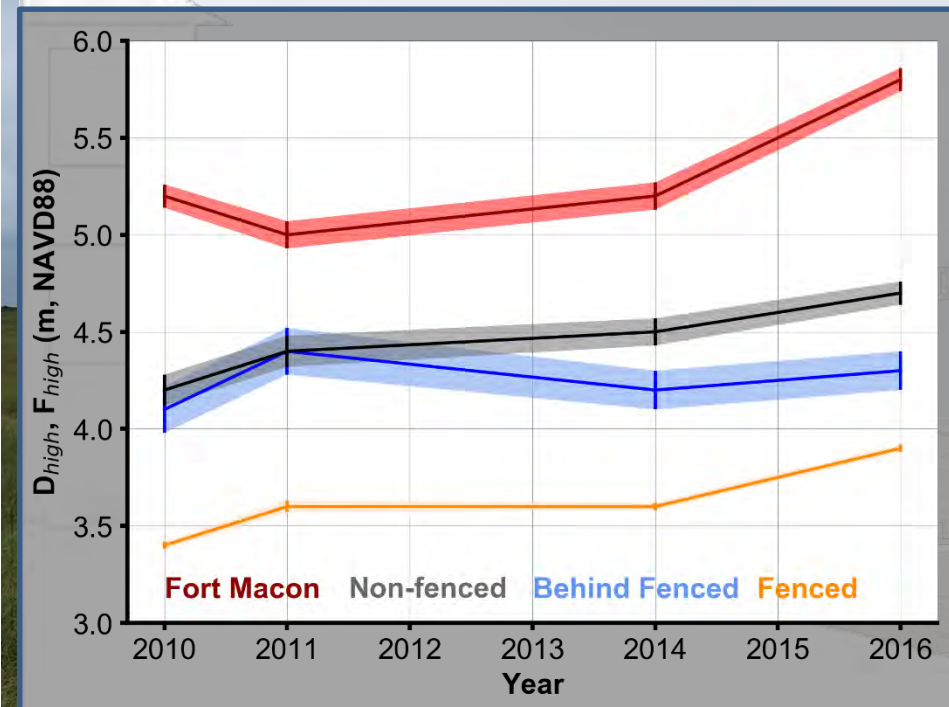
Modelled storm durations and NTRs consistent with local conditions for Bogue Banks, NC

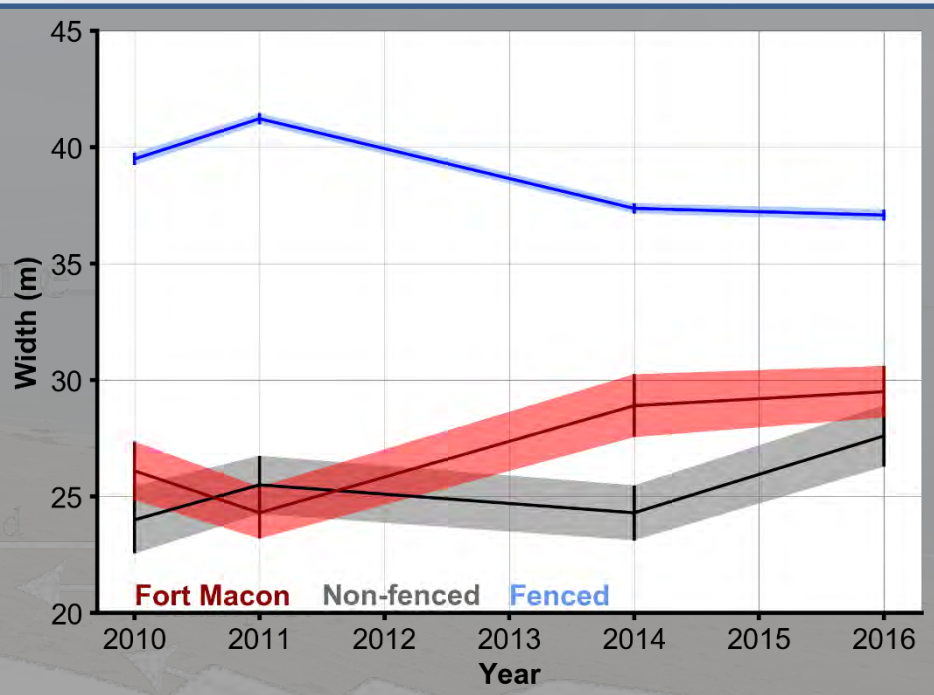
Observed Dune Aspect Ratios

- Measured dune volumes and aspect ratios from Bogue Banks, NC (1997-2016)
- Model parameter space (green box) appropriate with local morphology

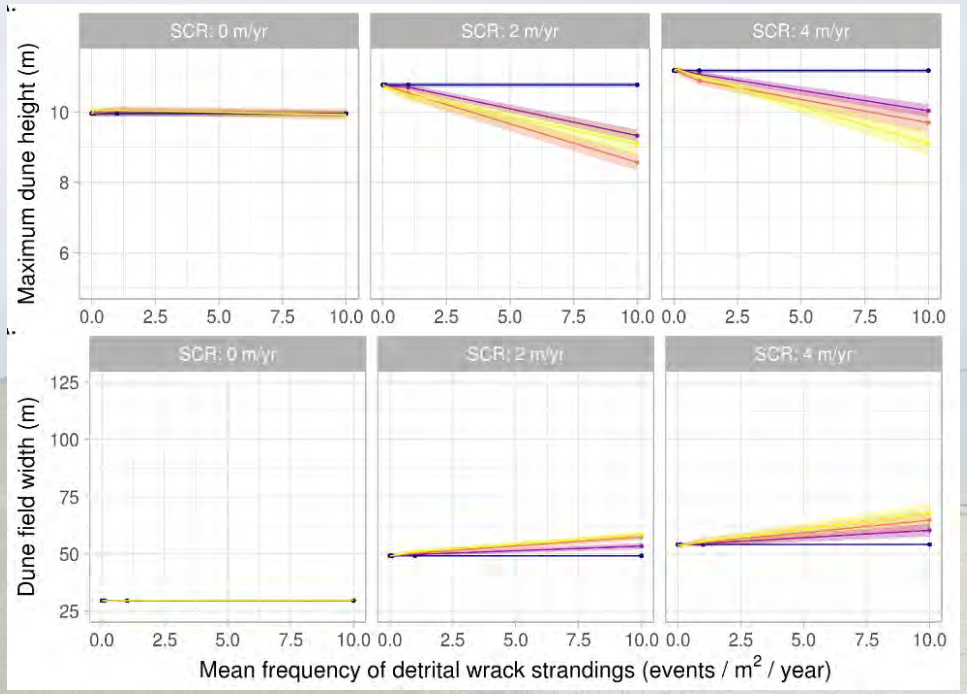


Human Influences on Dune Aspect Ratio





Human Influences on Dune Aspect Ratio



From Biel et al. (2019, *in prep*)

- Blue: Wrack removed
- Yellow: No wrack removal

- Wrack removal leads to taller and narrower dunes than where wrack is left in place
- Consistent with field observations by Nordstrom et al. (2012)

REMOTE SENSING AND MACHINE LEARNING AID IN EXAMINATIONS OF LAND CHANGE

JUSTIN RIDGE, ALEXANDER SEYMOUR, ANTONIO RODRIGUEZ,
EVERETTE NEWTON, PATRICK GRAY, JULIAN DALE,
DIEGO CHAMORRO, KENDALL JEFFERYS, DAVID JOHNSTON

Duke
NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY MARINE LAB

UNC
INSTITUTE OF MARINE SCIENCES

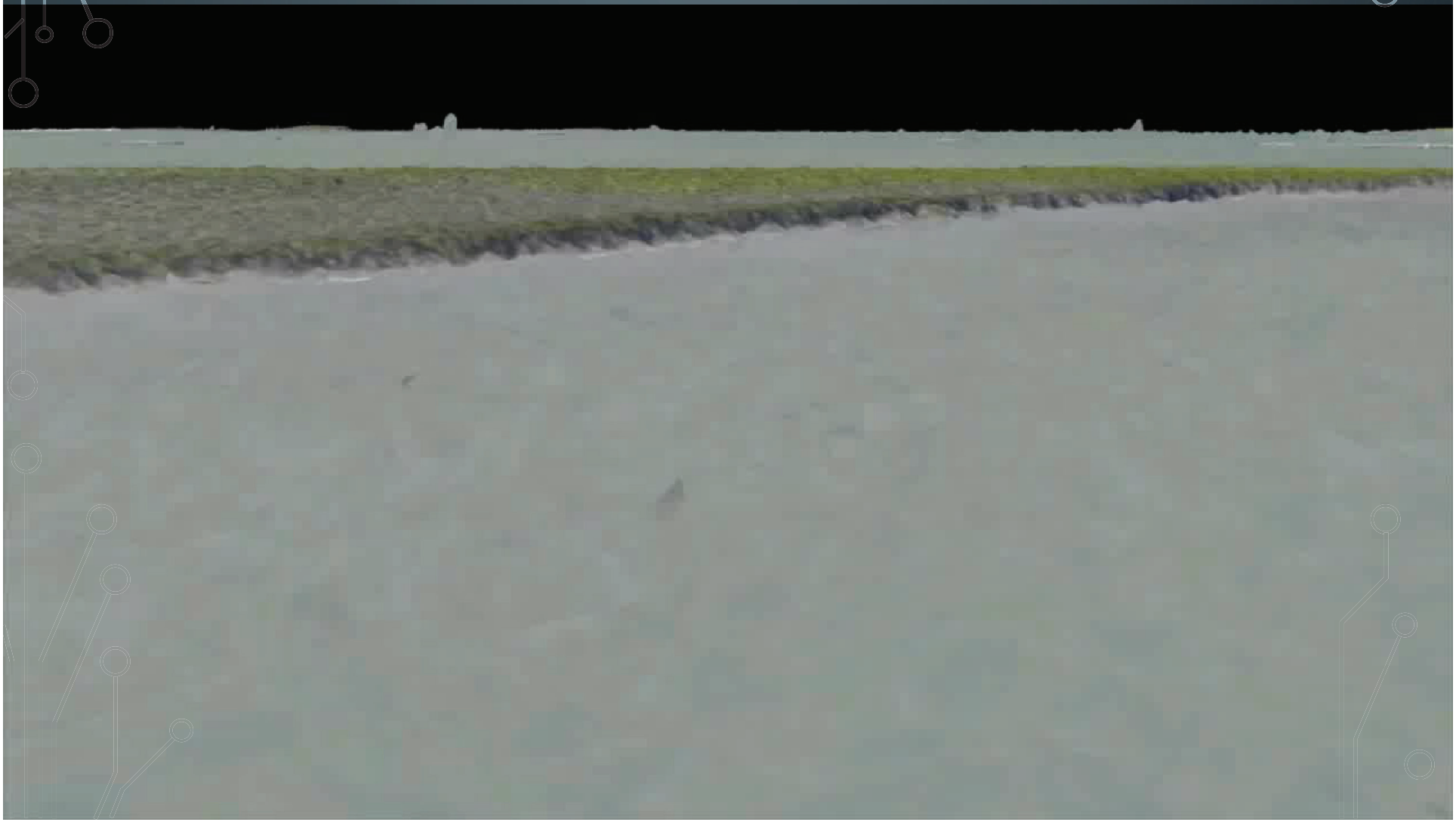
Marine Robotics & Remote Sensing

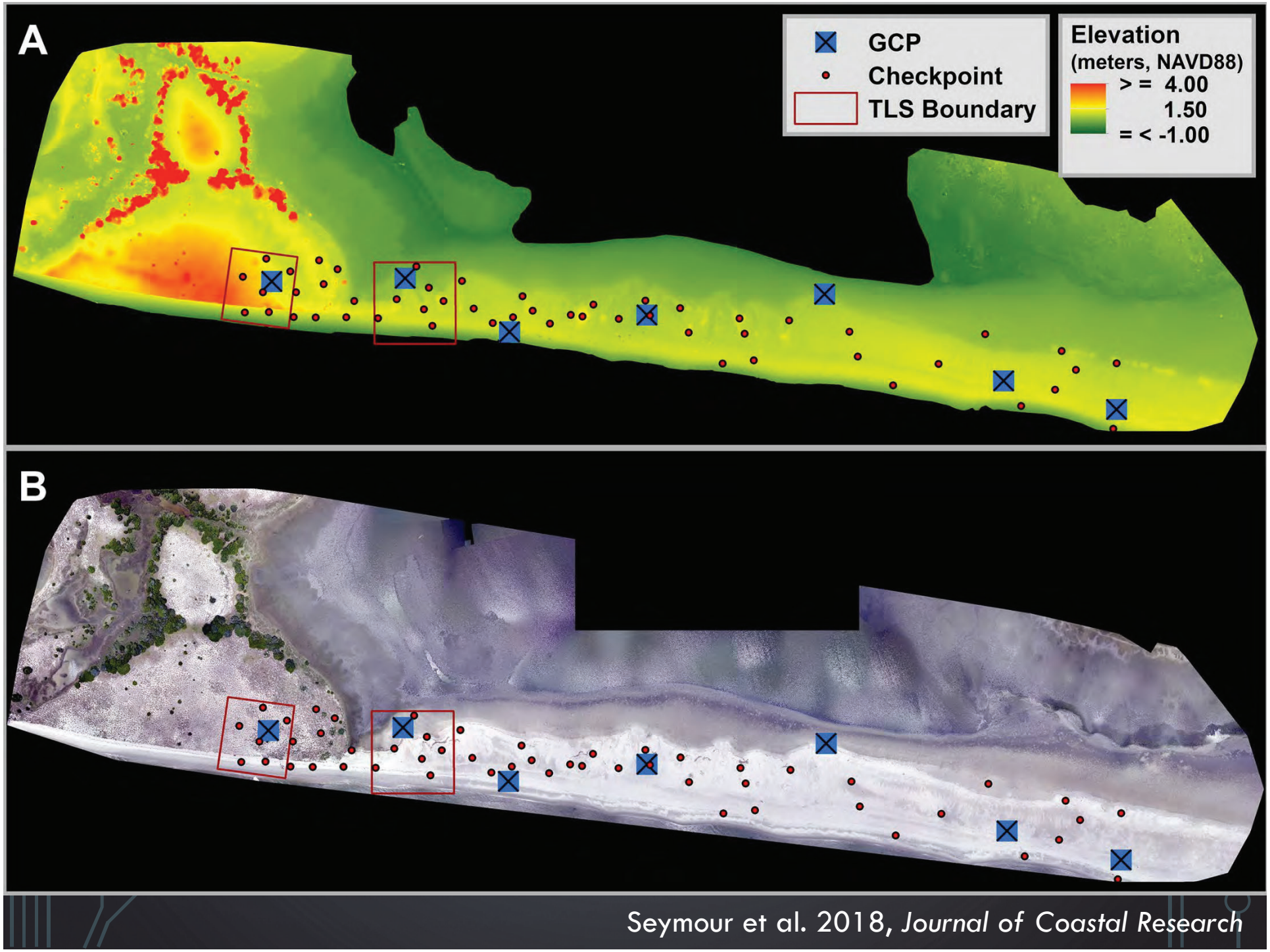
UNOCCUPIED AERIAL SYSTEMS (UAS)


A
NOAA Beaufort Tide Gauge
Town Marsh
Western Bird Shoal
Central Bird Shoal
Eastern Bird Shoal
Deep Creek
Dredged Shipping Channel
Bogue Banks
Beaufort Inlet
Back Sound
Shackleford Banks
Havelock
OPEN GROUNDS
Morehead City
Atlantic Beach
Emerald Isle
Beaufort
Dataset Coverage
June 2nd, 2016 (Baseline)
Oct 25th, 2016 (Disturbance)
Nov 23rd, 2016 (Recovery)
Sept 14th, 2017 (Trajectory 1)
May 22nd, 2018 (Trajectory 2)
Kilometers
0
1
2
N

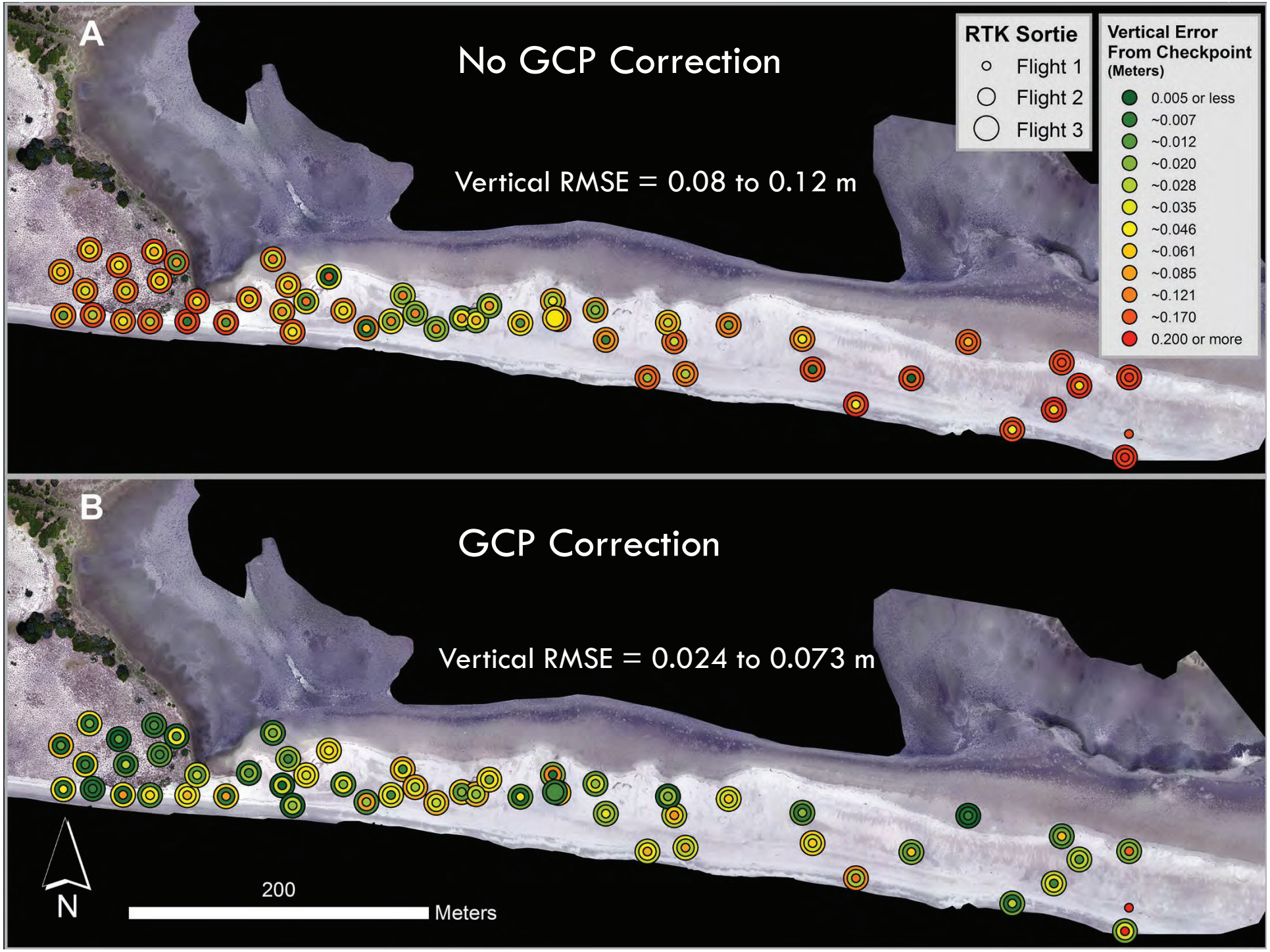

B
Baseline GCPs
Disturbance GCPs
Recovery GCPs
Trajectory GCPs
Washover Terrace
Foreshore
Tidal Flat
Beach Profiles
Town Marsh
Embayment
Vegetated
Dune
Escarpment
1
2
3
4
5
6
9
7
8
10
Meters
0
200

STRUCTURE FROM MOTION (SFM)





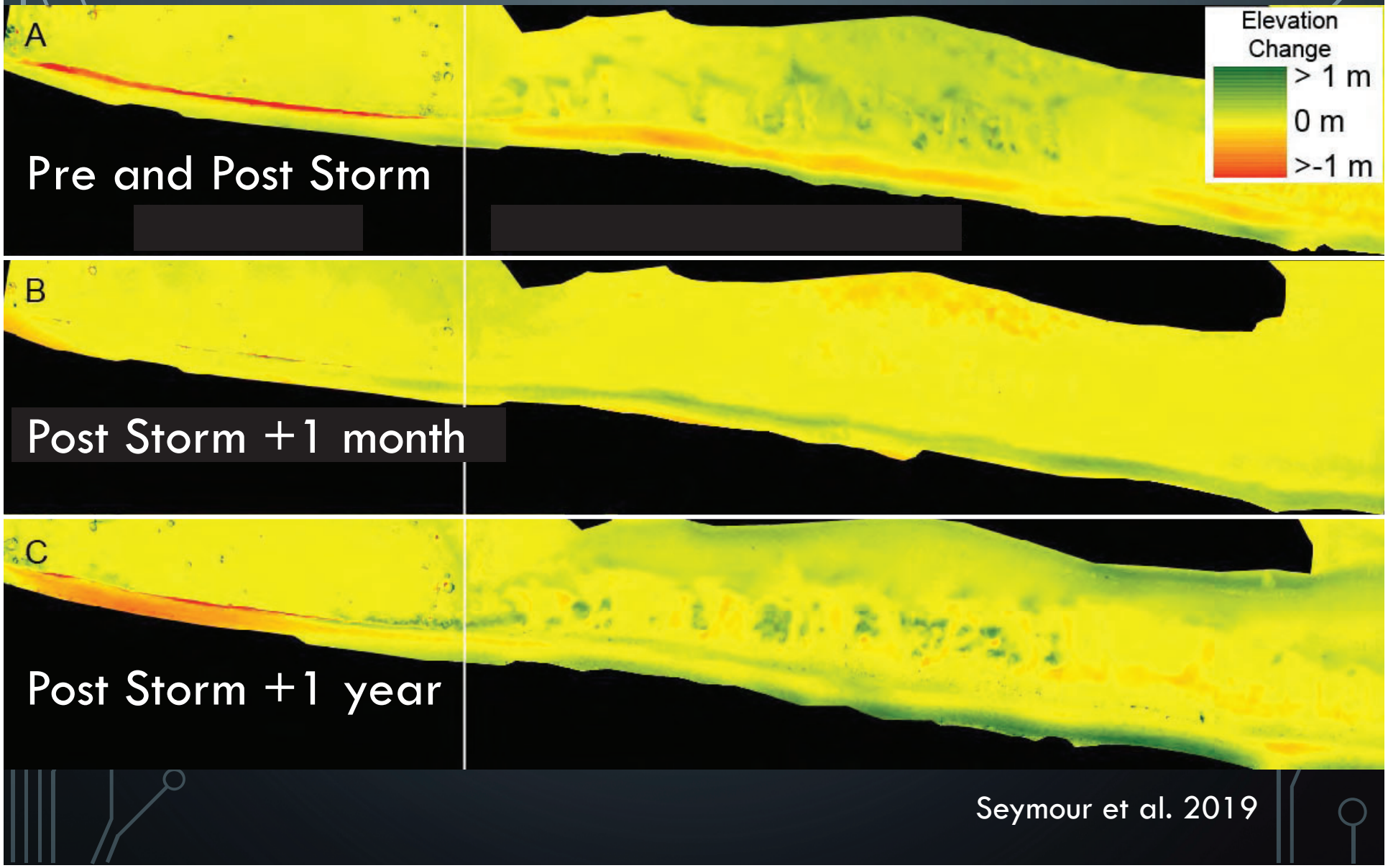
Seymour et al. 2018, *Journal of Coastal Research*


A
No GCP Correction
Vertical RMSE = 0.08 to 0.12 m
RTK Sortie
Flight 1
Flight 2
Flight 3
Vertical Error From Checkpoint (Meters)
0.005 or less
~0.007
~0.012
~0.020
~0.028
~0.035
~0.046
~0.061
~0.085
~0.121
~0.170
0.200 or more
B
GCP Correction
Vertical RMSE = 0.024 to 0.073 m
N
200
Meters

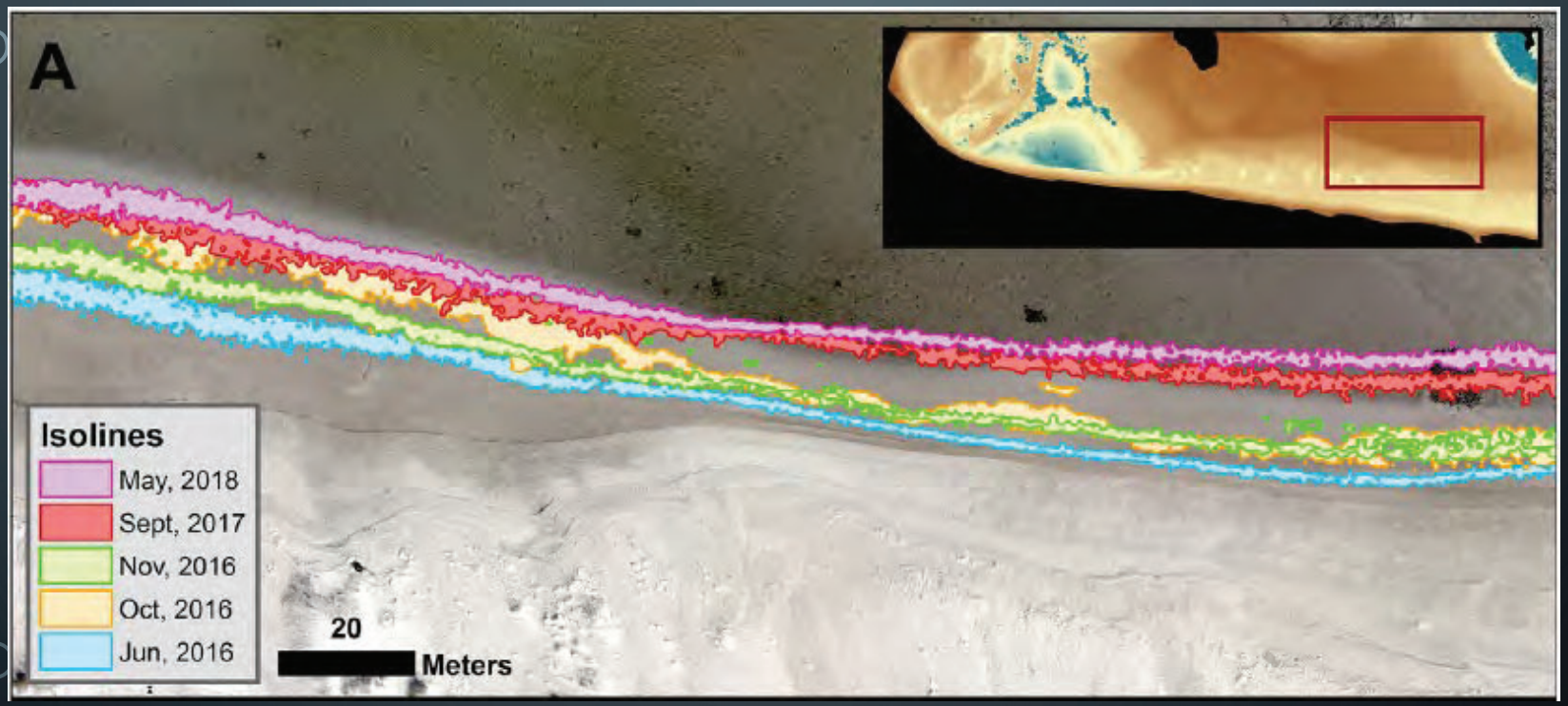
HURRICANE MATTHEW

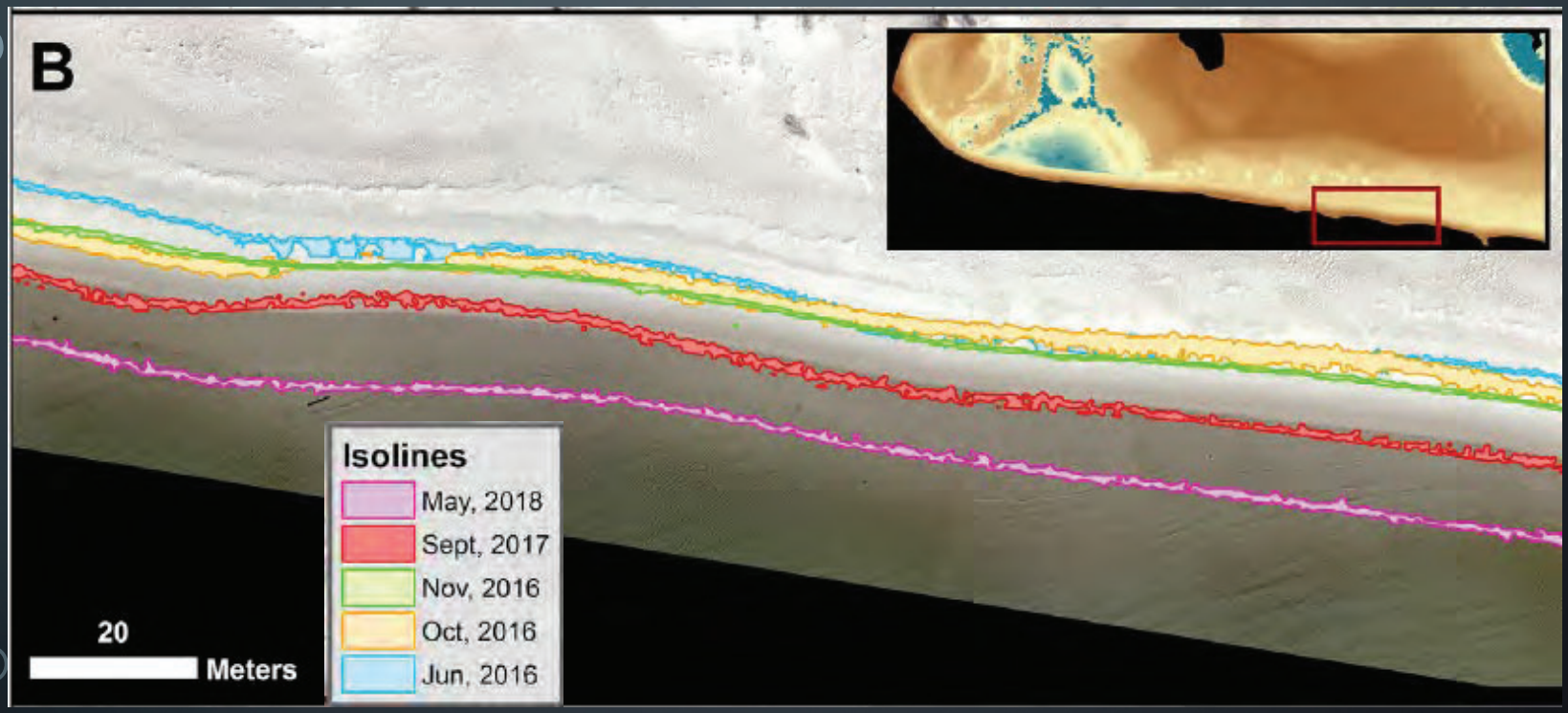
HURRICANE MATTHEW

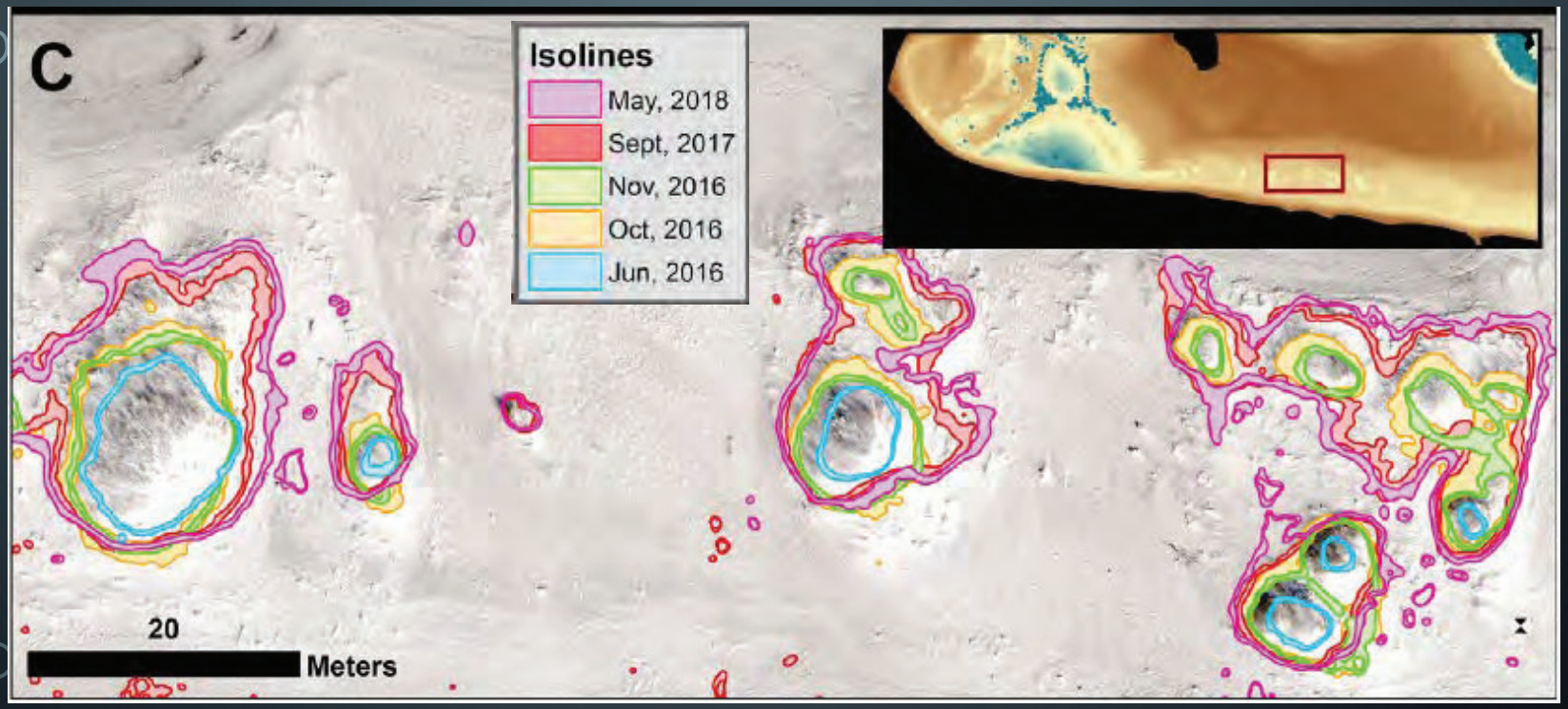
Hurricane Matthew Subtraction Maps

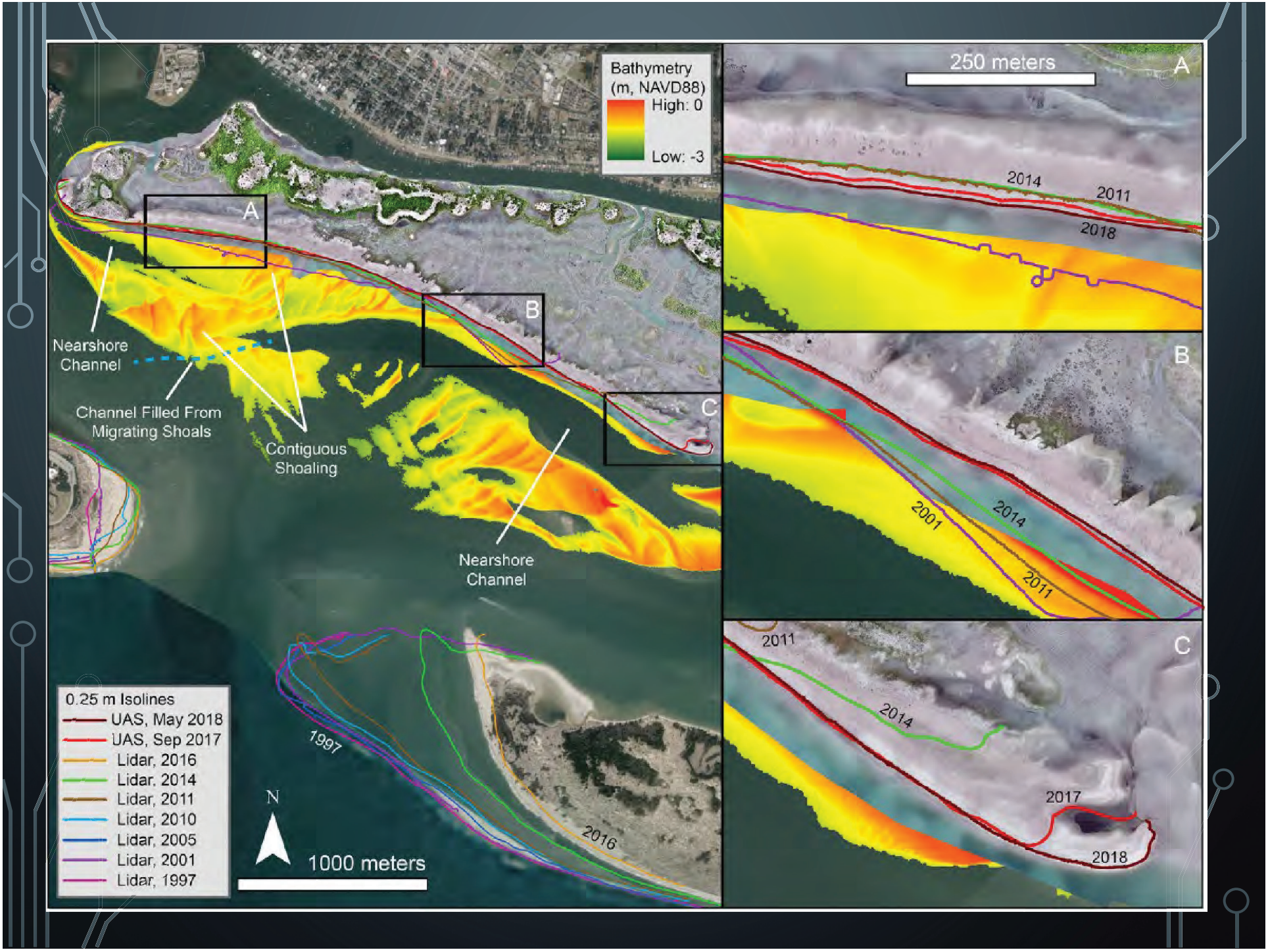


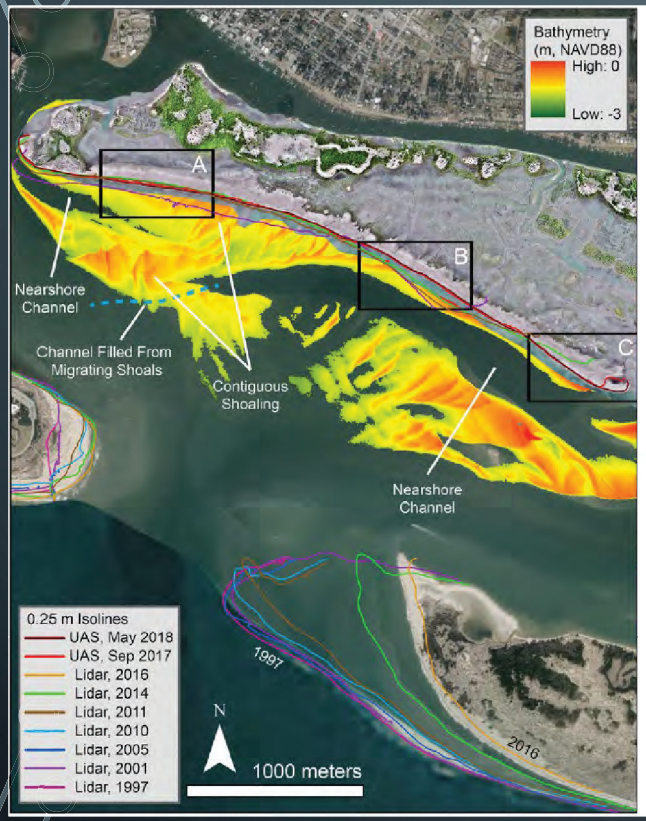
Seymour et al. 2019


A
Isolines
May, 2018
Sept, 2017
Nov, 2016
Oct, 2016
Jun, 2016
20
Meters


B
Isolines
May, 2018
Sept, 2017
Nov, 2016
Oct, 2016
Jun, 2016
20
Meters


C
Isolines
May, 2018
Sept, 2017
Nov, 2016
Oct, 2016
Jun, 2016
20
Meters


Bathymetry
(m, NAVD88)
High: 0
Low: -3
A
B
C
Nearshore
Channel
Channel Filled From
Migrating Shoals
Contiguous
Shoaling
Nearshore
Channel
0.25 m Isolines
UAS, May 2018
UAS, Sep 2017
Lidar, 2016
Lidar, 2014
Lidar, 2011
Lidar, 2010
Lidar, 2005
Lidar, 2001
Lidar, 1997
N
1000 meters
1997
2016
250 meters
2014
2011
2018
2001
2014
2011
2011
2014
2017
2018


Bathymetry
(m, NAVD88)
High: 0
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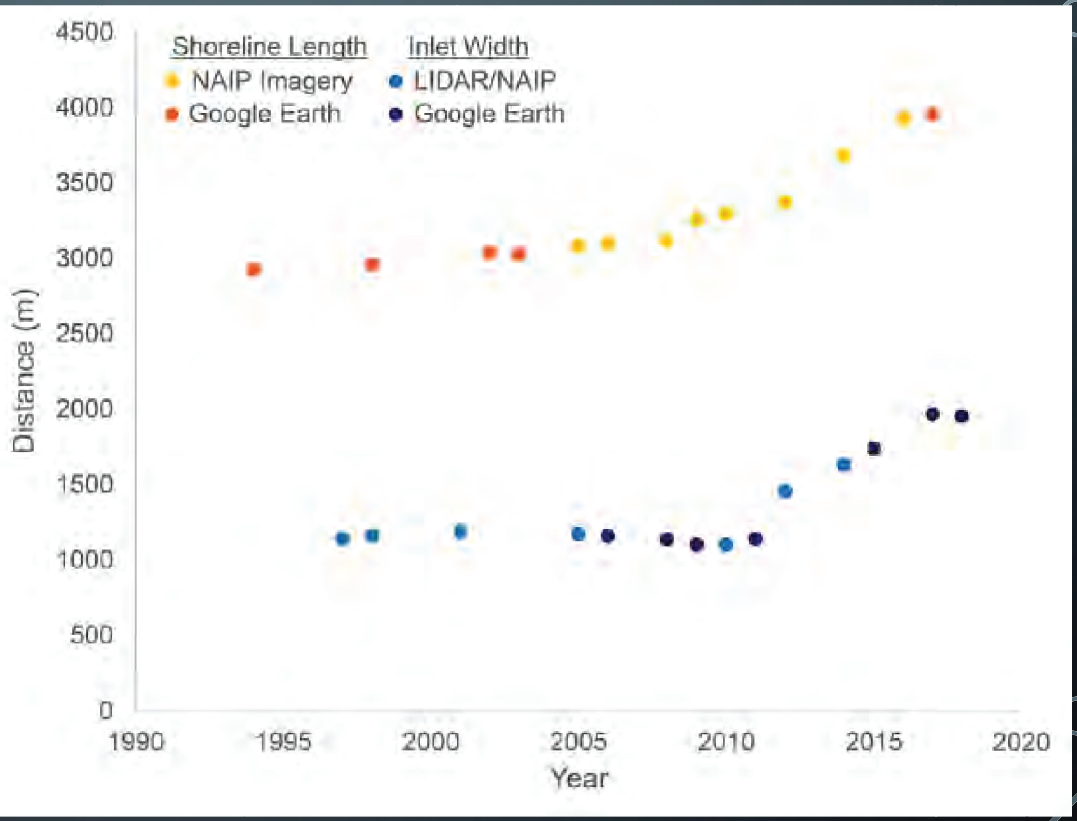
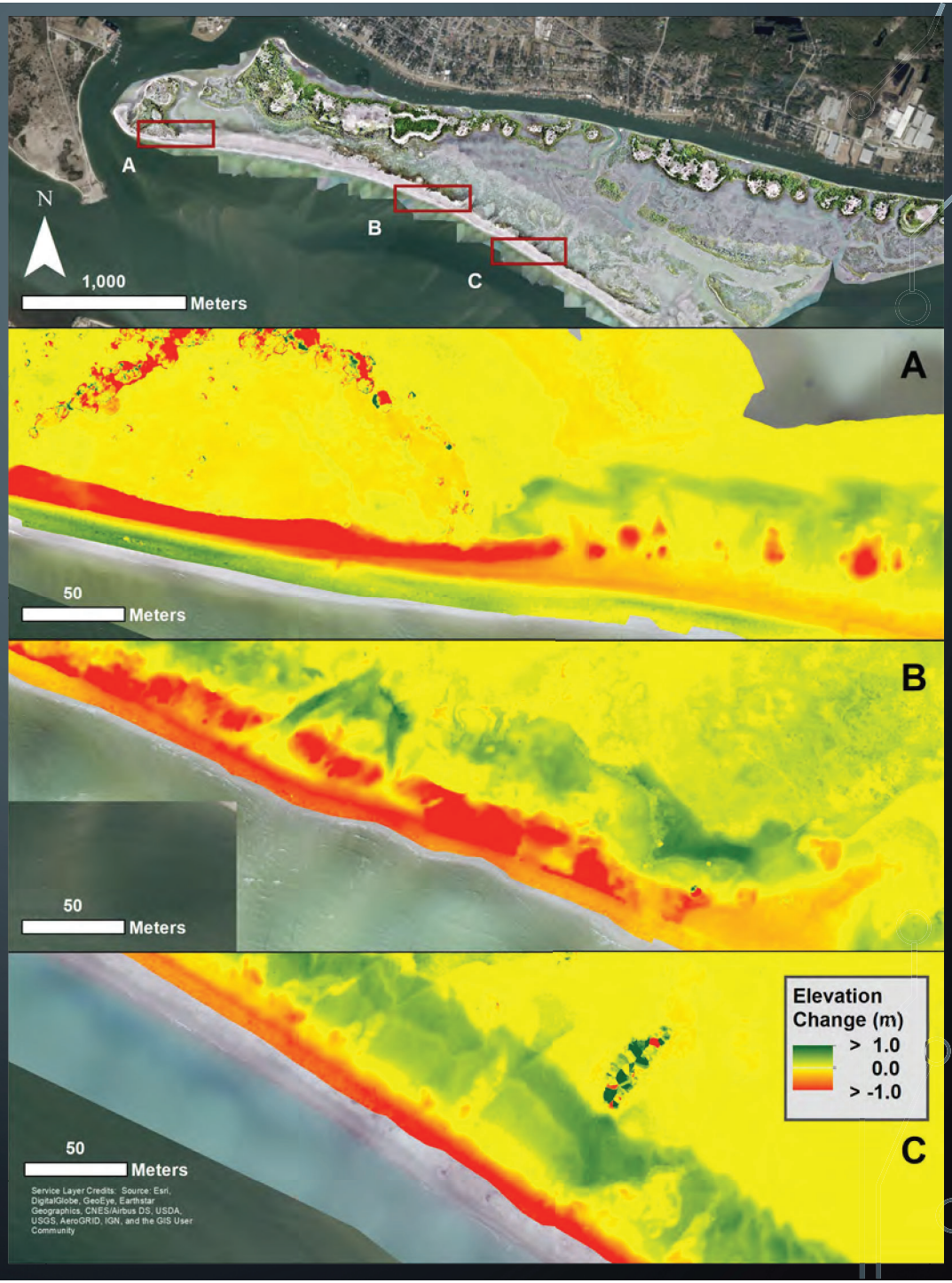
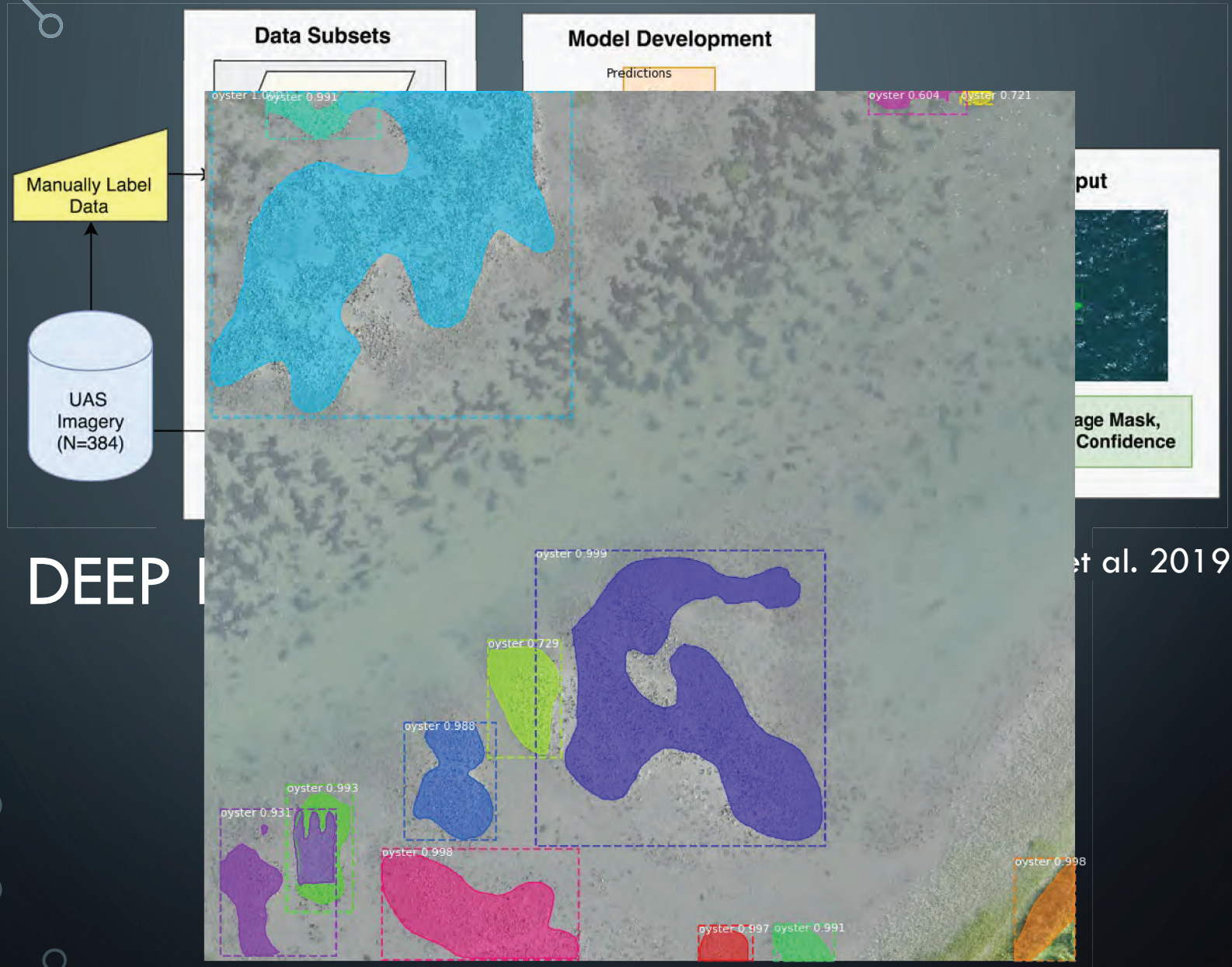
A
B
C
Nearshore
Channel
Channel Filled From
Migrating Shoals
Contiguous
Shoaling
Nearshore
Channel
0.25 m Isolines
UAS, May 2018
UAS, Sep 2017
Lidar, 2016
Lidar, 2014
Lidar, 2011
Lidar, 2010
Lidar, 2005
Lidar, 2001
Lidar, 1997
1997
2016
N
1000 meters


Shoreline Length
NAIP Imagery
Google Earth
Inlet Width
LIDAR/NAIP
Google Earth
Distance (m)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1990
1995
2000
2005
2010
2015
2020
Year

HURRICANE FLORENCE



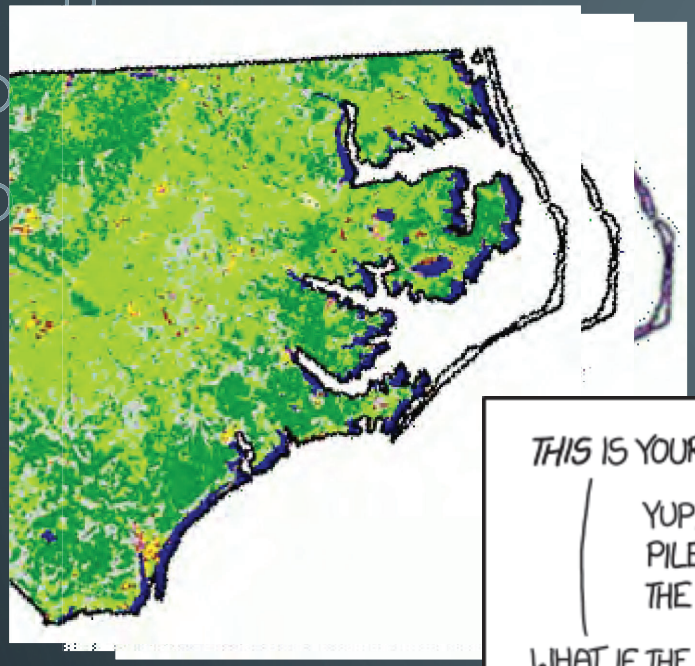
DEEP L



t al. 2019

Ridge et al. 2019

DEEP LEARNING FOR LAND COVER CHANGE



xkcd.com

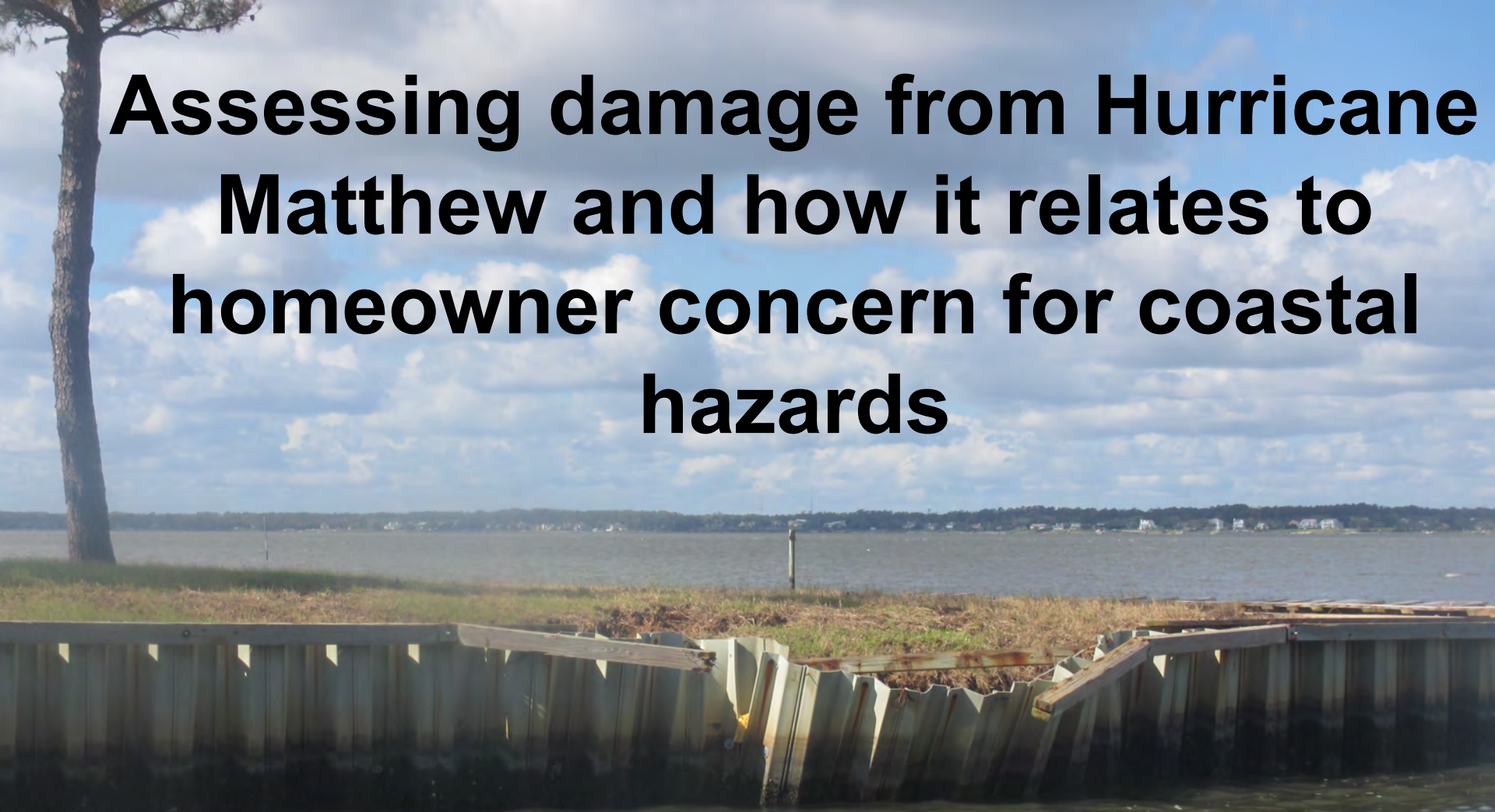
Funding through:

QUESTIONS?

NC Sentinel Site Cooperative

PEOPLE

Assessing damage from Hurricane Matthew and how it relates to homeowner concern for coastal hazards



Carter Smith

NC Coastal Conference

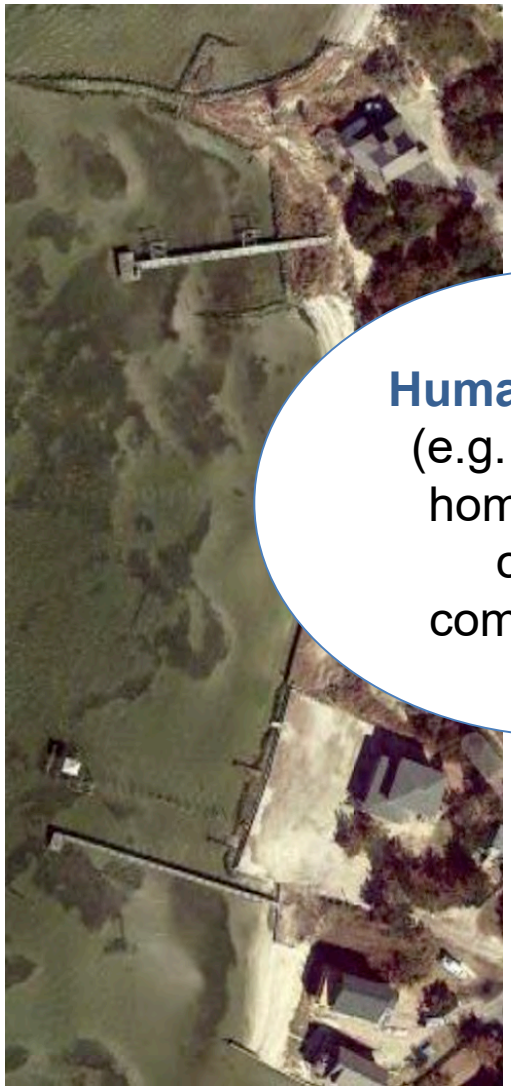
November 19th, 2019

UNC INSTITUTE OF MARINE SCIENCES

Duke NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY MARINE LAB

SENTINEL SITE COOPERATIVES

Coastal Shorelines: Social-Ecological Systems



Actions & management
(e.g. shoreline hardening)

Human systems
(e.g. waterfront homeowners, coastal communities)

Coastal ecosystems
(e.g. saltmarshes, oyster reefs, seagrass beds)

Ecosystem services
(e.g. recreation, habitat provision, wave damping)

Shoreline Hardening

14% of the U.S. sheltered coastline is hardened

Riprap revetment

Bulkhead

Hardened Shorelines

Cut-off the connection to land

Habitat loss

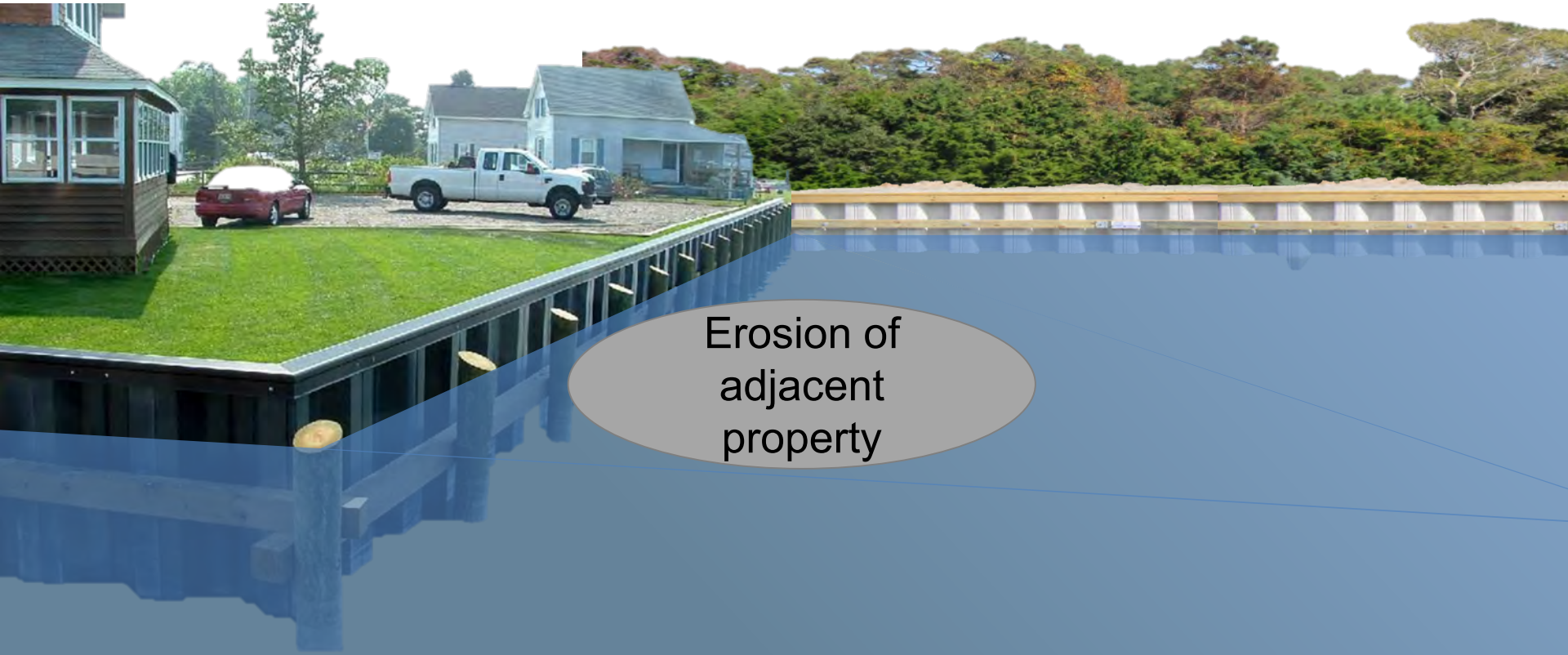
Reduce biodiversity

Hardened Shorelines

Cut-off the connection to land

Habitat loss

Reduce biodiversity



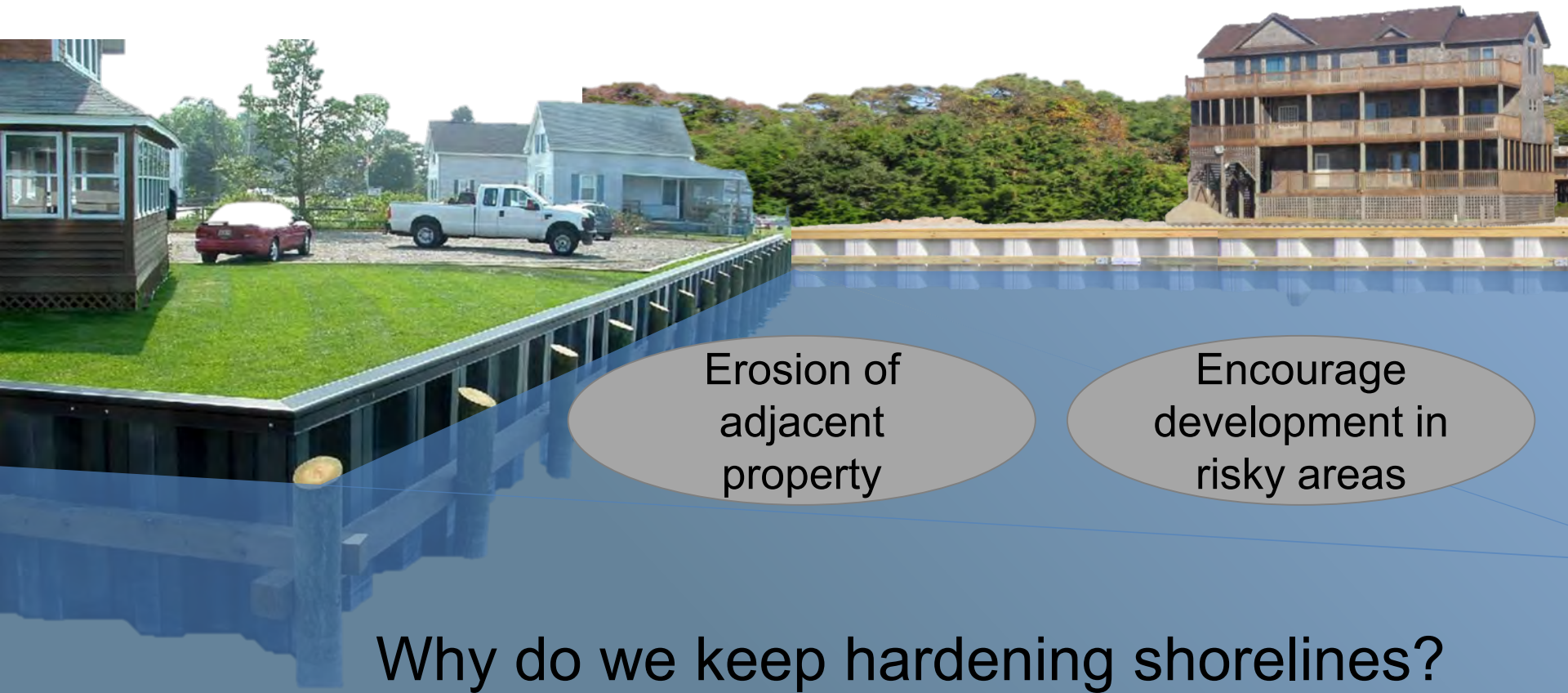
Erosion of adjacent property

Hardened Shorelines

Cut-off the connection to land

Habitat loss

Reduce biodiversity

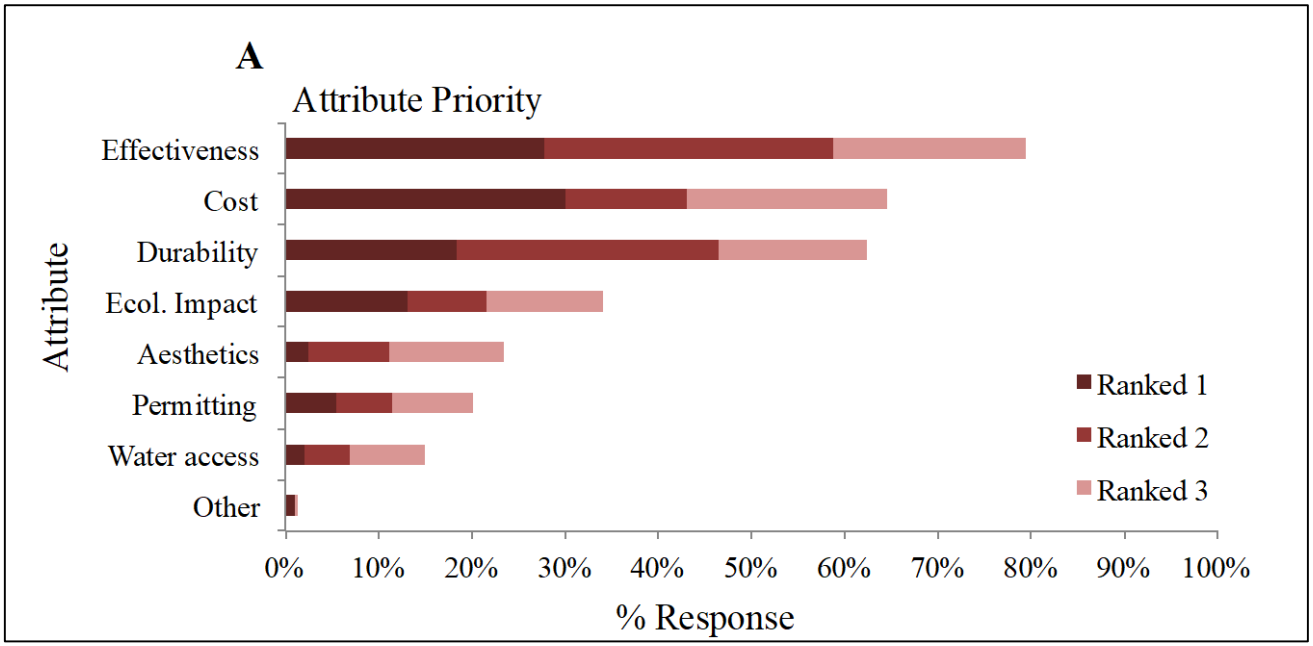


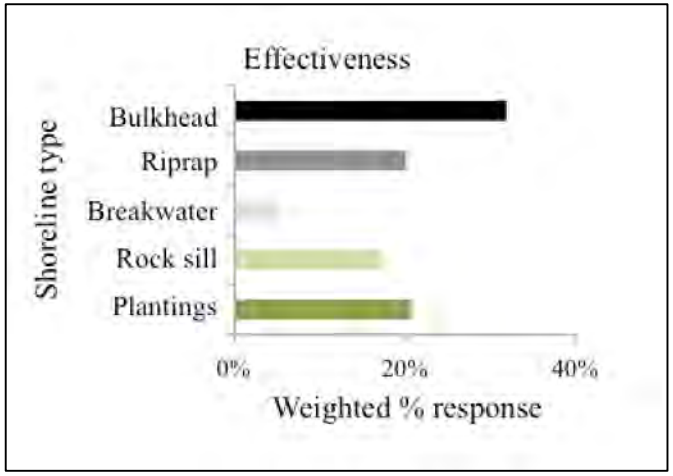
Erosion of adjacent property

Encourage development in risky areas

Why do we keep hardening shorelines?

What do homeowners prioritize when choosing how to stabilize their shorelines?

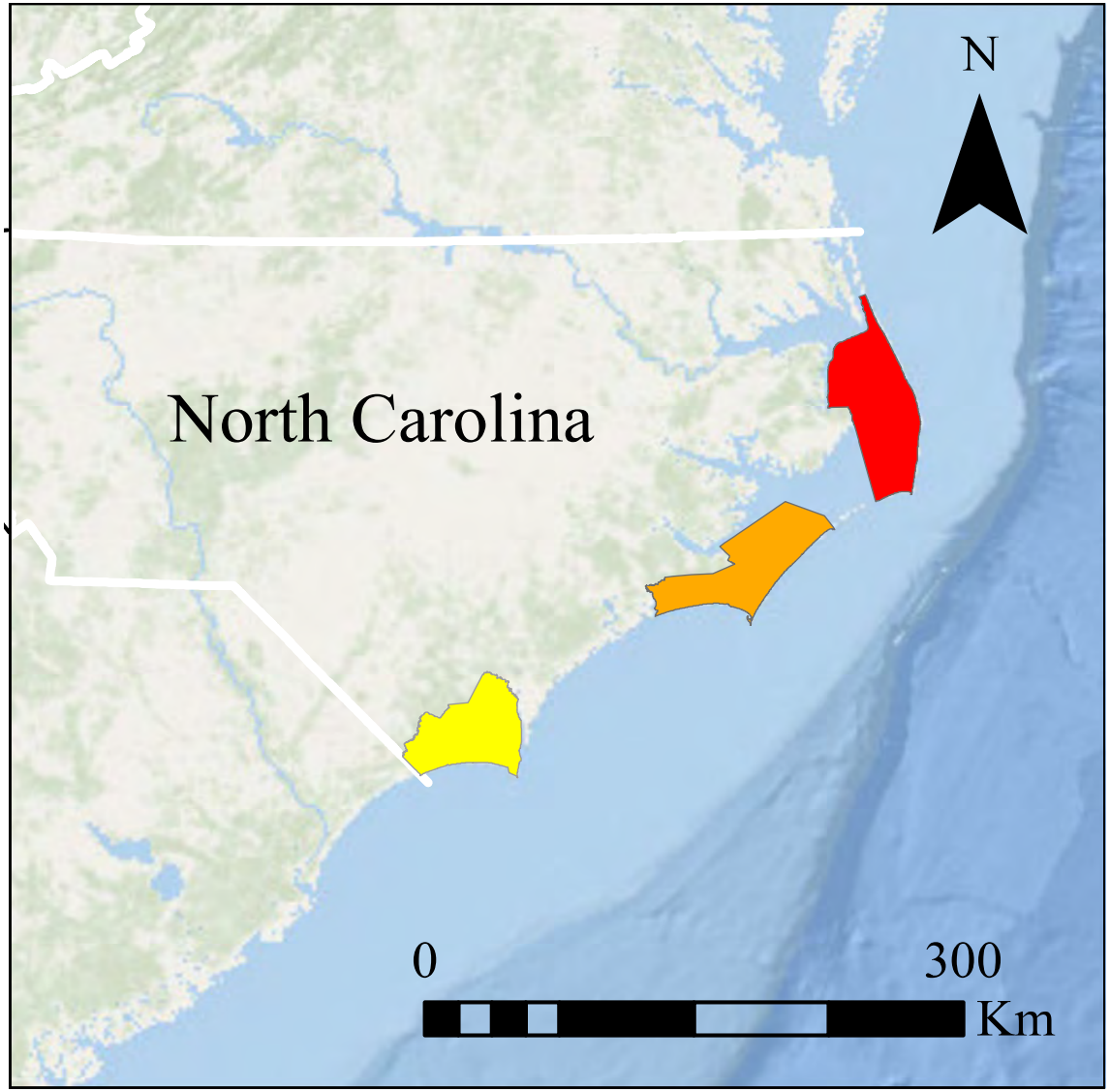




[Smith *et al. 2017* Marine Policy]

Homeowner Survey Questions

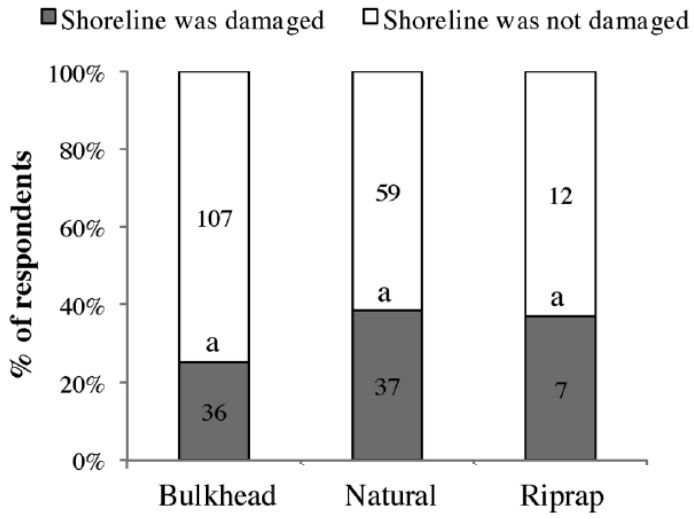
1. Did hardened shorelines protect homes better than natural shorelines during Hurricane Matthew (2016)?
2. Do shoreline management strategies impact perceptions of risk?
3. Do hurricanes impact perceptions of risk?

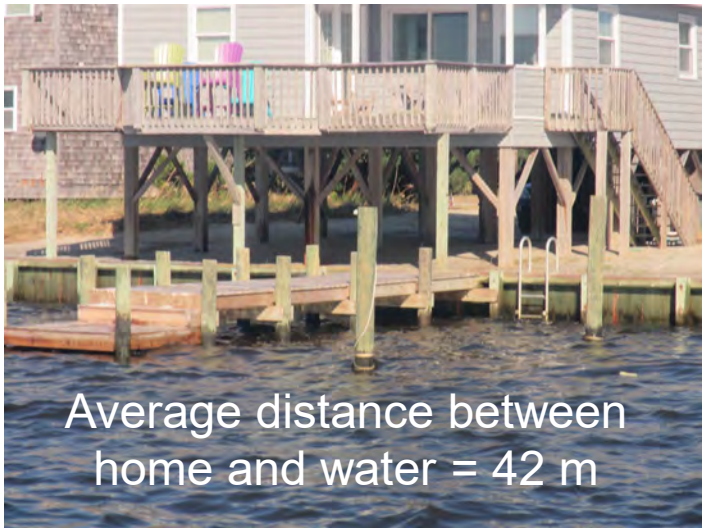


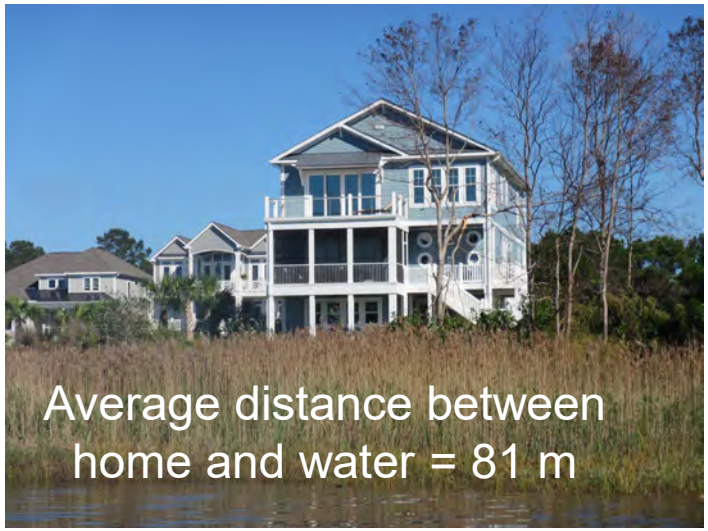
Survey distribution

- Spring/Summer 2017 (post- Hurricane Matthew)
- Dual method (online and by mail)
- ~1500 surveys distributed in Dare, Carteret, and Brunswick counties to waterfront homeowners
- ~300 responses (20% response rate)
- All data is homeowner reported

Shoreline and home damage during Hurricane Matthew

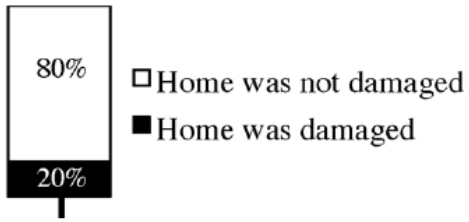






[Smith & Scyphers 2019]

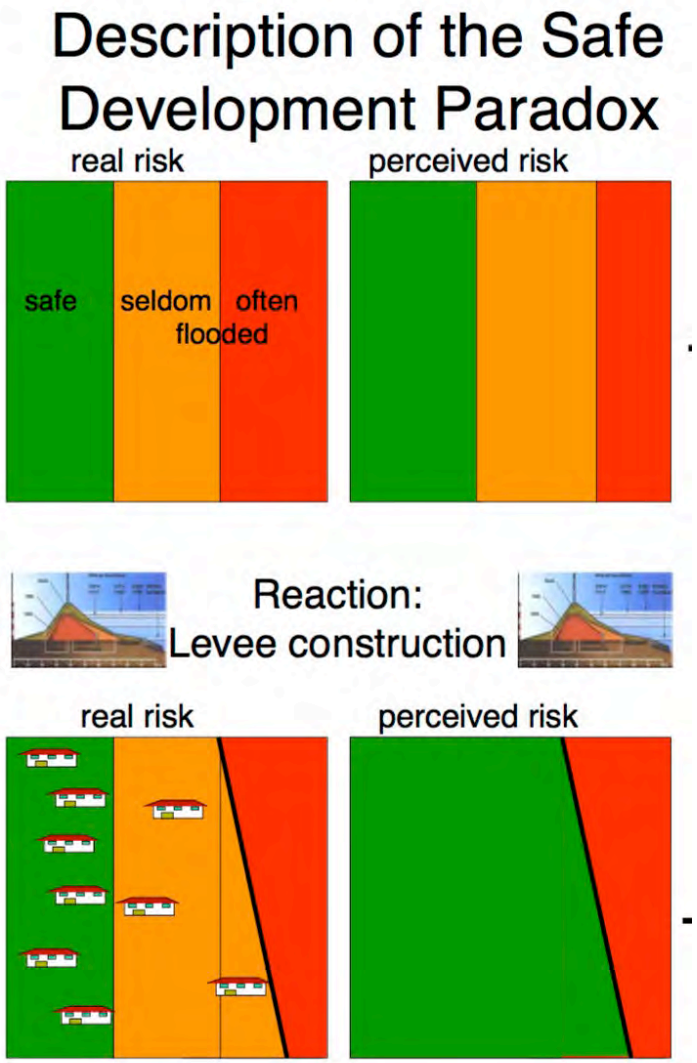
Home damage during Hurricane Matthew



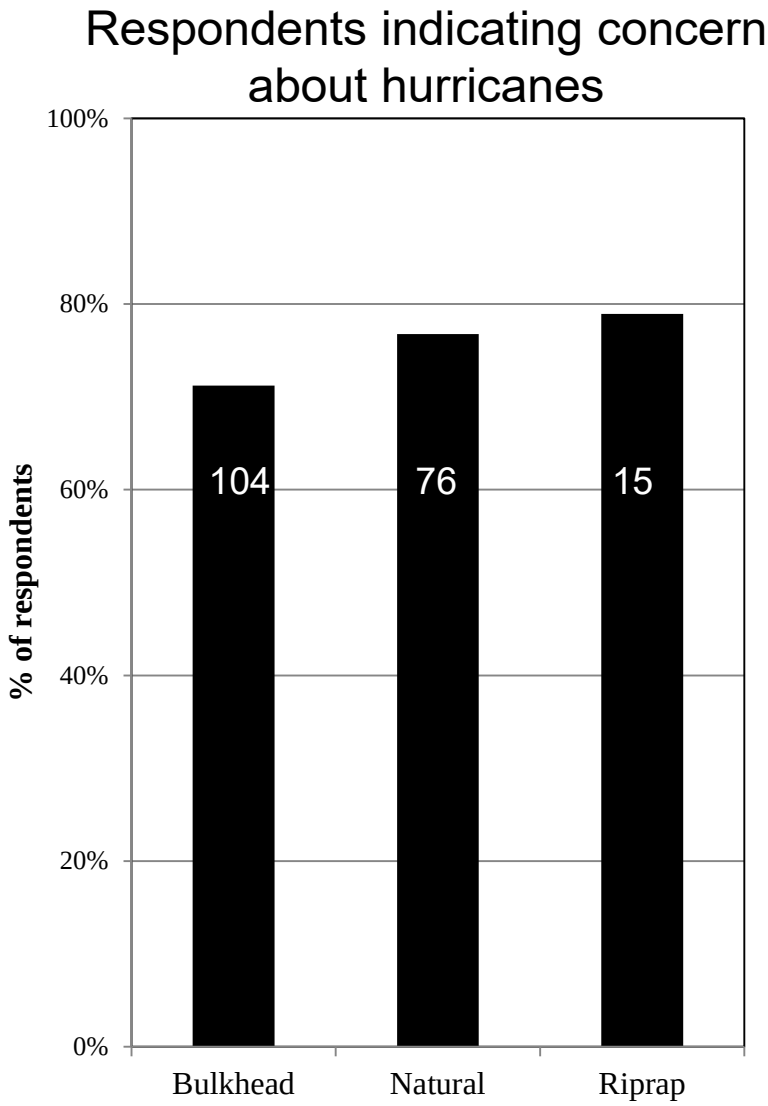
- County
- Average fetch
- Direction of fetch
- Shoreline type
- Shoreline damage during Matthew
- Home damaged during previous hurricane
- Flood zone
- Distance between house and shoreline
- Is the house elevated?

[Smith & Scyphers 2019]

Do shoreline management strategies impact perceptions of vulnerability?



[Burby *et al.* 2006]



Do hurricanes impact perceptions of SLR vulnerability?

When will SLR become a problem for your home?

Category	%	n
0-25 years	13.9	42
26-50 years	26.1	79
51-75 years	18.8	57
75+ years	23.8	72
Never	17.5	53
Total	100.0	303

- County
- Waterfront type
- Shoreline type
- Shoreline damage during Matthew
- Home damaged during Matthew
- Flood zone
- Years in NC
- Gender
- Age
- Level of Education
- Income

Take Home Points

- Bulkheads did not eliminate the risk of living close to the water during Hurricane Matthew
- Hurricanes may act as signaling events that make homeowners feel more vulnerable to other hazards

Acknowledgements

Steven Scyphers
Rachel Gittman
Pete Peterson
Isabelle Neylan
Jane Harrison
Monica Gregory
Whitney Jenkins
Tancred Miller

Questions?

NWS Advancements & Building Partnerships Over the Past 10 Years: Improving Readiness for Hazardous Weather Events

David Glenn
National Weather Service
Newport/Morehead City, NC

Outline

- NWS Mission & Vision
- Tropical: Storm Surge Changes and Enhancements
- Flash Flooding: Flood warning paradigm changes across the Carolinas
- Weather-Ready Nation initiative & WRN ambassadors: help build a WRN by becoming a message multiplier

NATIONAL WEATHER SERVICE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME | FORECAST | PAST WEATHER | SAFETY | INFORMATION | EDUCATION | NEWS | SEARCH | ABOUT

The National Weather Service (NWS)

Weather.gov > About the NWS

About the NWS
National Program

About

Serving you in every community in the U.S. Check out who we are and what we do!

NWS Mission

Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.

NWS Vision

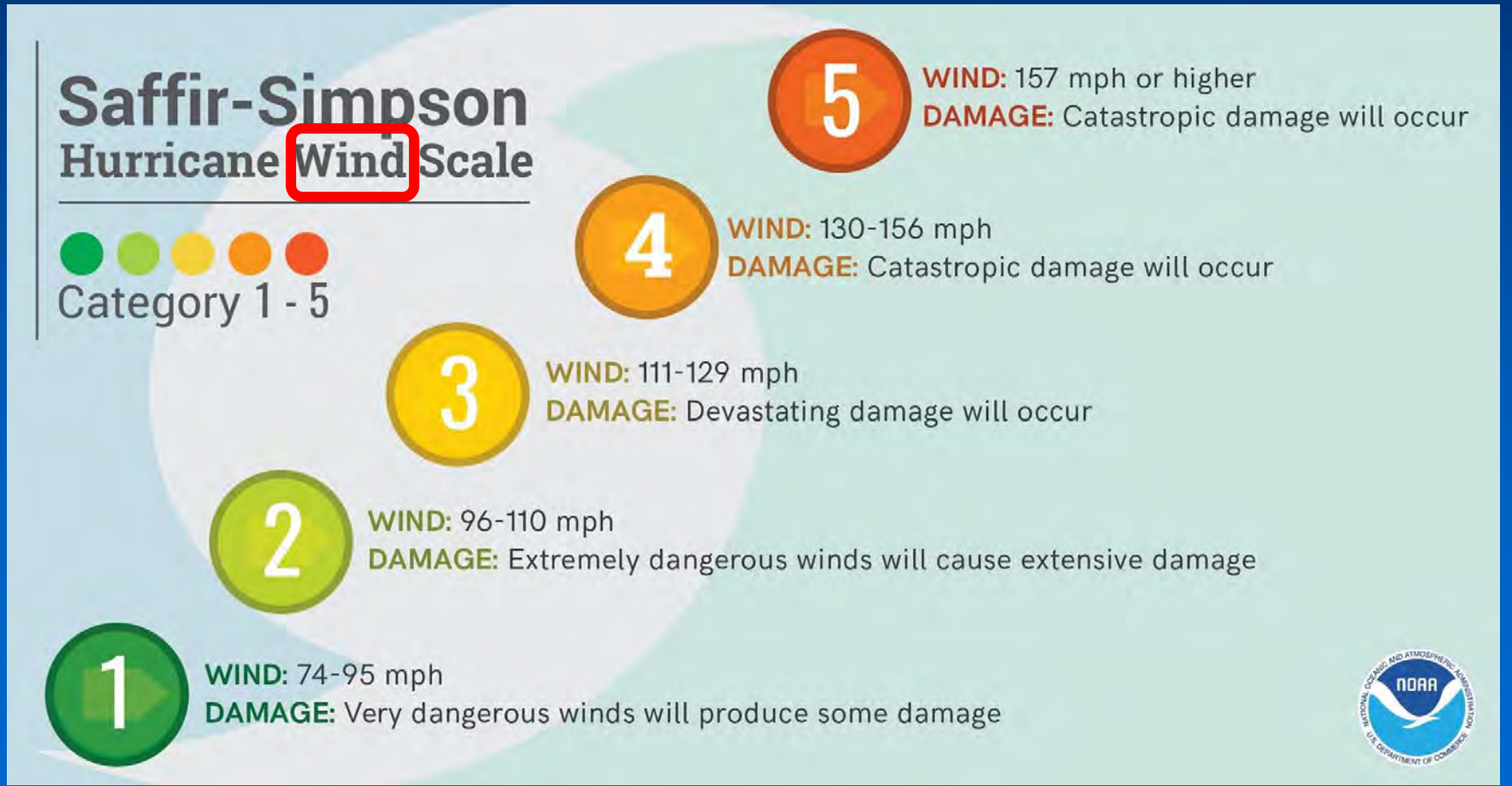
A Weather-Ready Nation: Society is prepared for and responds to weather, water, and climate-dependent events.

Weather-Ready Nation Story

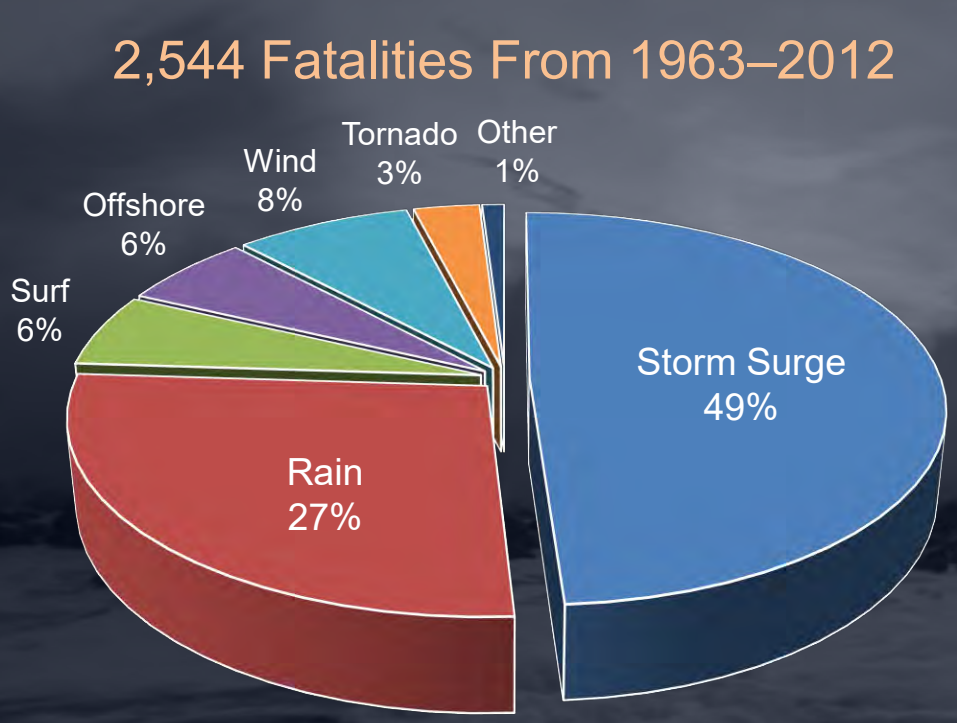
Accurate weather forecasts do not always result in a good outcome. The National Weather Service (NWS) learned this difficult...**Read more**

Saffir/Simpson Hurricane Scale

Used to categorize hurricane strength and to give an estimate of potential property damage



It's Water, Not Wind

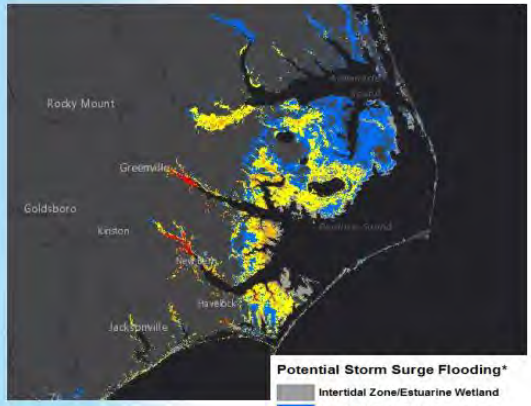


- Almost 50% the deaths are due to storm surge
- Over 80% of deaths are due to water
- Wind causes less than 10% of deaths

Edward N. Rappaport, 2014: Fatalities in the United States from Atlantic Tropical Cyclones: New Data and Interpretation. Bull. Amer. Meteor. Soc., 95, 341–346.

NATIONAL WEATHER SERVICE

Potential Storm Surge Flooding Map

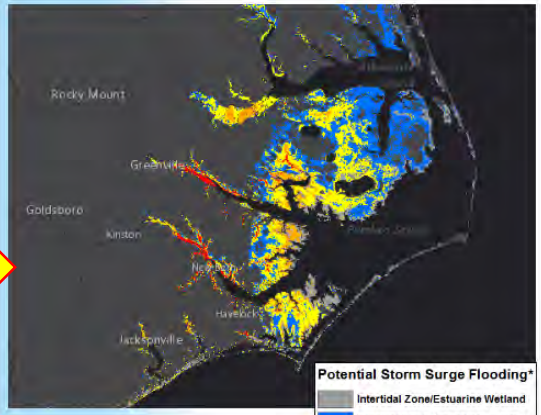


- 6 to 12 feet above ground level from Cape Fear to Cape Lookout, including the Neuse and Pamlico River
- Cape Lookout to Ocracoke Inlet of 5 to 8 feet

Weather Forecast Office
Morehead City, NC
Follow us
http://www.weather.gov/mhx/
Presentation Created
9/11/2018 7:27 AM

NATIONAL WEATHER SERVICE

Potential Storm Surge Flooding Map



Click here to view the Potential Storm Surge Flooding Map

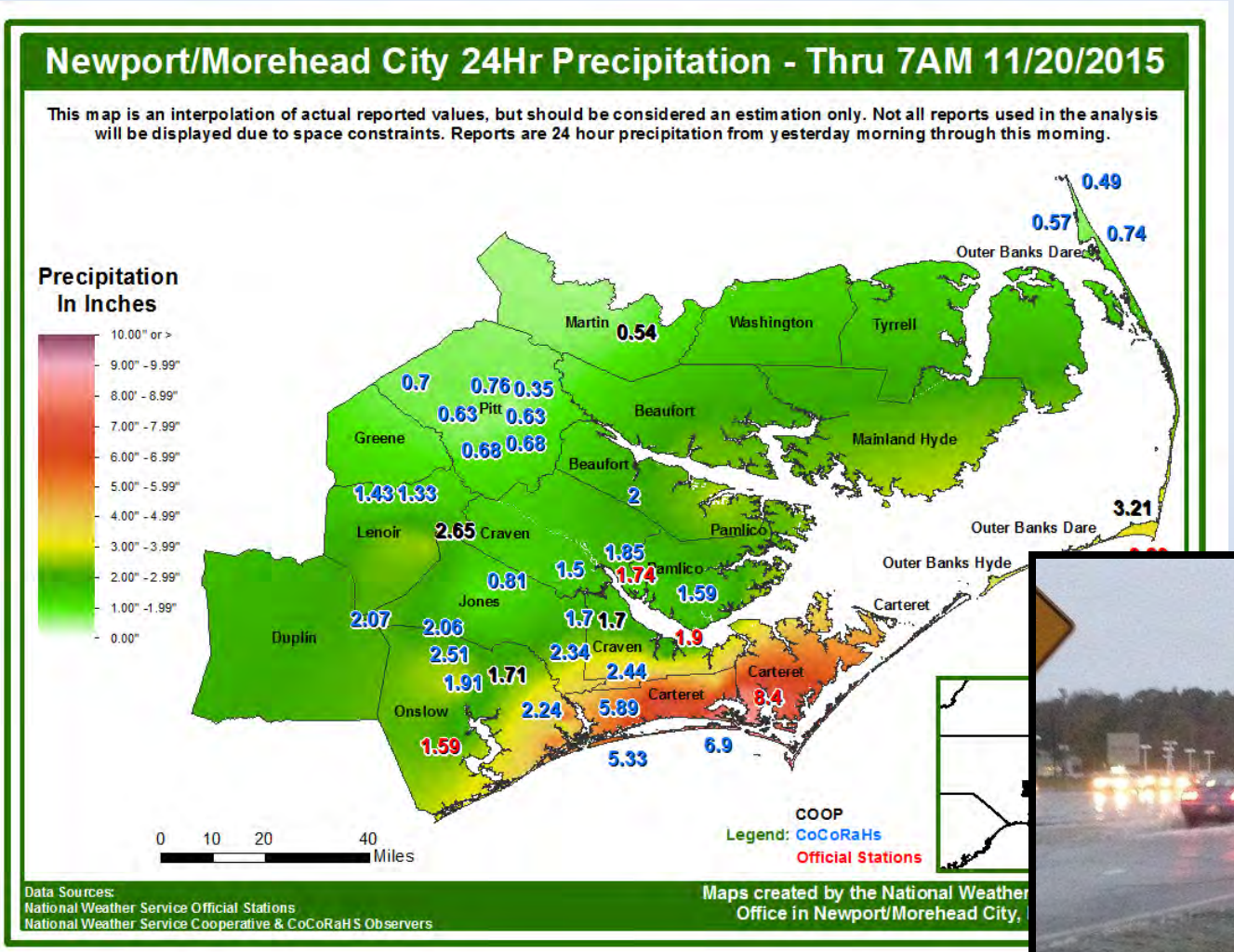
- 9 to 13 feet above ground from Cape Fear to Cape Lookout, including the Neuse and Pamlico River
- Cape Lookout to Ocracoke Inlet of 6 to 9 feet
- Ocracoke Inlet to NC/VA border 4 to 6 feet

Weather Forecast Office
Morehead City, NC
Follow us
http://www.weather.gov/mhx/
Presentation Created
9/11/2018 4:23 PM

Advisory, Areal Flood, or Flash Flood?

How would a forecaster categorize this?
How would the public categorize this?
How would Emergency Managers categorize this?

Significant Flooding in Carteret County



Much of the area received, 1 to 2 inches. Higher amounts can be seen along the Crystal Coast and OBX. Beaufort received over 8" of rain with nearly 3" falling in one hour.

Water starts to flood HWY-70 in Morehead City.

While the coastal plain can endure a lot of rain, the intensity of the rainfall combined with antecedent conditions yielded significant flooding.

New Two Tiered Approach Designed

- A two-tiered approach ultimately simplifies our messaging (Flood Advisories and Flash Flood Warnings).
- Issue Flash Flood Watches only when FFW thresholds could be met.
- After the rain stops, or the danger of flash flooding is subsiding, issue a Flood Advisory to ramp down from the FFW as needed.
- Flash Flood Emergencies can be used in very rare circumstances when catastrophic flooding is possible or occurring. Confirmation/support is obtained from EMs prior to issuing.

New Coastal Carolina Flash Flood Warning Criteria

For the potential or occurrence of…

- ***A simplified two-tier approach*** focusing on only Flood Advisories and Flash Flood Warnings will help ensure a consistent and better understood approach for future flood events.
- ***Decision making can be tied to EAS activation.*** Therefore, action and better decision making could occur if Flash Flood Warnings are issued during higher impact events. ***It will also enable WEA Alerts to better alert the public.***

- o Any sudden rise in water that could lead to fatalities or significant damage
- o Dam failures

If flooding occurs or is expected, but will not reach any of the above thresholds then simply issue a **Flood Advisory**

The Job Doesn't End with Forecasts and Warnings

"First, it should be understood that forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by users of the forecasts."

"What is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting"

– by Allan H. Murphy; Weather and Forecasting (June 1993)

NOAA Strategic Outcome:
A Weather, Water, Climate-Ready Nation

"Ready, Responsive, Resilient"

Better forecasts and warnings…
Actionable environmental intelligence…
Consistent products and services…
Connecting forecasts to <u>decisions</u>.

Involves the entire US Weather, Water and Climate Enterprise WORKING TOGETHER

We have 10,000+ WRN Ambassadors

Realizing the Full Value of Forecasts:
Connecting Forecasts to Critical Decisions

Generating forecasts and warnings + **Forecast advice within a decision environment** *"Impact-based Decision Support Services"* = **Realizing Intrinsic Value and Mission Success**

Provide the best hydrological and meteorological forecasting in the world

Develop relationships and know partner needs

Explain uncertainty

Support partner decision making before, during, and after events

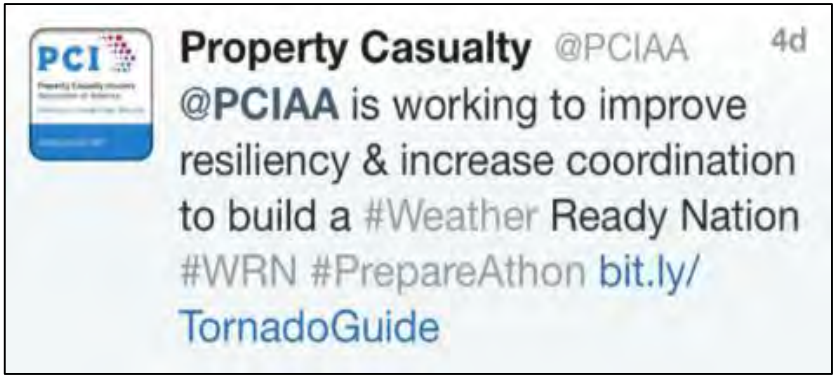
Embed when needed

Build trust

Government Can't Do It Alone:
WRN Ambassador Initiative

- **Who can be a part of and contribute toward building a Weather-Ready Nation?**
  - All levels of government
  - Academia
  - Businesses & non-profits
  - Weather-dependent sectors of economy
- **Formal recognition of organizations that work with NOAA toward building a Weather-Ready Nation**
  - Promote WRN messages and themes
  - Engage with NOAA on potential collaborations
  - Share success stories
  - Serve as an "Example"

AMBASSADOR™
WRN
WEATHER-READY NATION



Visit: weather.gov/wrn

Midgett Realty
November 16 at 3:28 PM ·

IMPORTANT NOTICE FOR TRAVELERS COMING TO AND DEPARTING HATTERAS ISLAND:

Due to the very hazardous conditions currently affecting clearing operations and public travel on NC12 and given the forecast is calling for weather conditions to further deteriorate overnight, NCDOT will be closing NC12 from the Marc Basnight Oregon Inlet Bridge to Rodanthe at 5:00pm today. With almost zero visibility and high confidence ocean over wash will occur associated with the next high tide, in order to ensure the safety of the traveling public this closure is being implemented. NCDOT crews will be back out early tomorrow to assess and determine if and when the closure can be lifted however continued hazardous conditions can also be expected to continue for Sunday.

69 15 Comments 74 Shares

Like Comment Share

Most Relevant

Write a comment...

Diana Brenkert Prayers for the islands and everyone's safety 🙏🙏
Like · Reply · 1d 1

Stacie Birchett Stay safe, everyone!
Like · Reply · 1d 1

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WEATHER-READY NATION AMBASSADORS

One way the National Weather Service has connected with the enterprise and beyond to organizations that are users of weather information across the nation is through the WRN Ambassadors Initiative, created in 2013. The WRN Ambassadors Initiative weaves the entire weather enterprise into the fabric of local, regional, and national communities of decision-makers: addressing and ensuring awareness, preparedness, and responsiveness to extreme weather, water, and climate events, an essential step for public safety, mitigating property loss, and accelerating recovery efforts after the event. As of

Dear Friends,
As swimming conditions continue to strengthen, we do ask that you utilize the utmost caution if you decide to go for a swim, particularly this week as there is a large storm in the Atlantic basin. Please share this graphic with all members of your party and have a real discussion about swim safety, regardless of your age and/or strength as a swimmer.

We are wishing each of you a happy and safe Labor Day from the beach!

Questions?


NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

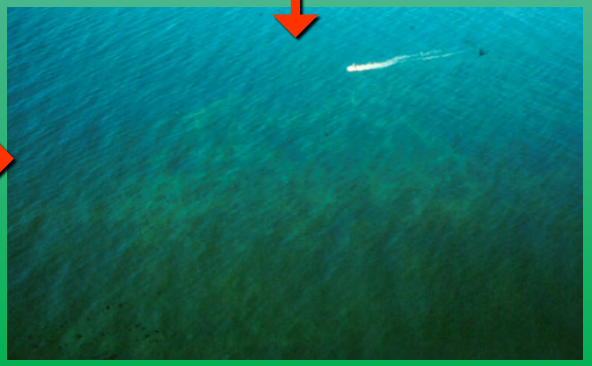
NC Sentinel Site Cooperative

WATER QUALITY

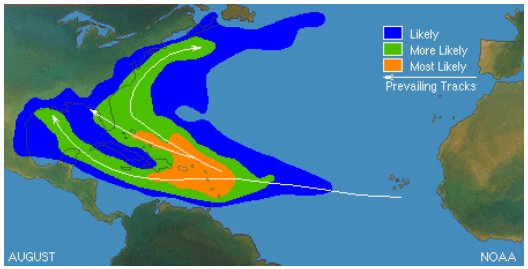
Impacts of the "new normal" in tropical cyclone rainfall and flooding on assessing and managing estuarine/coastal water quality

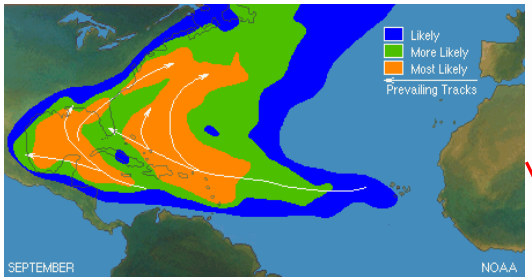
Hans Paerl[1], Nathan Hall[1], Alexandria Hounshell[2], Karen Rossignol[1] and Chris Osburn[3]
[1]UNC-CH Inst. of Marine Sciences, Morehead City, NC, [2]Dept. of Biological Sciences, Virginia Tech. Univ., Blacksburg, VA,
[3]NC State Univ, Dept. of Marine, Earth and Atmospheric Sciences, Raleigh. NC

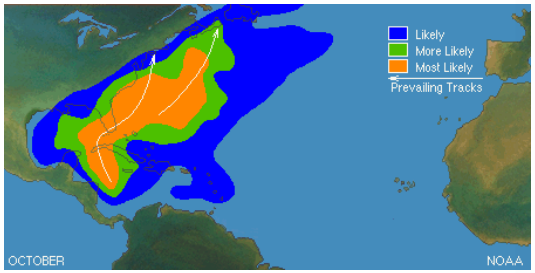
http://paerllab.web.unc.edu

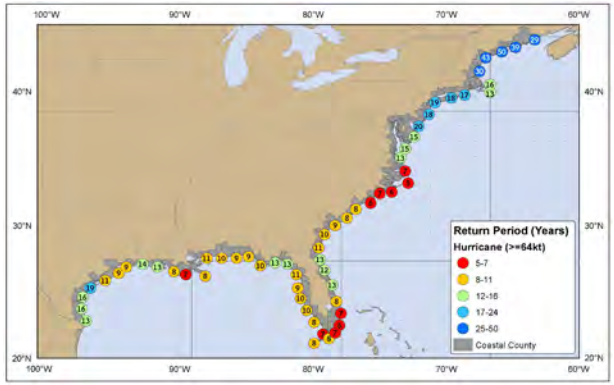


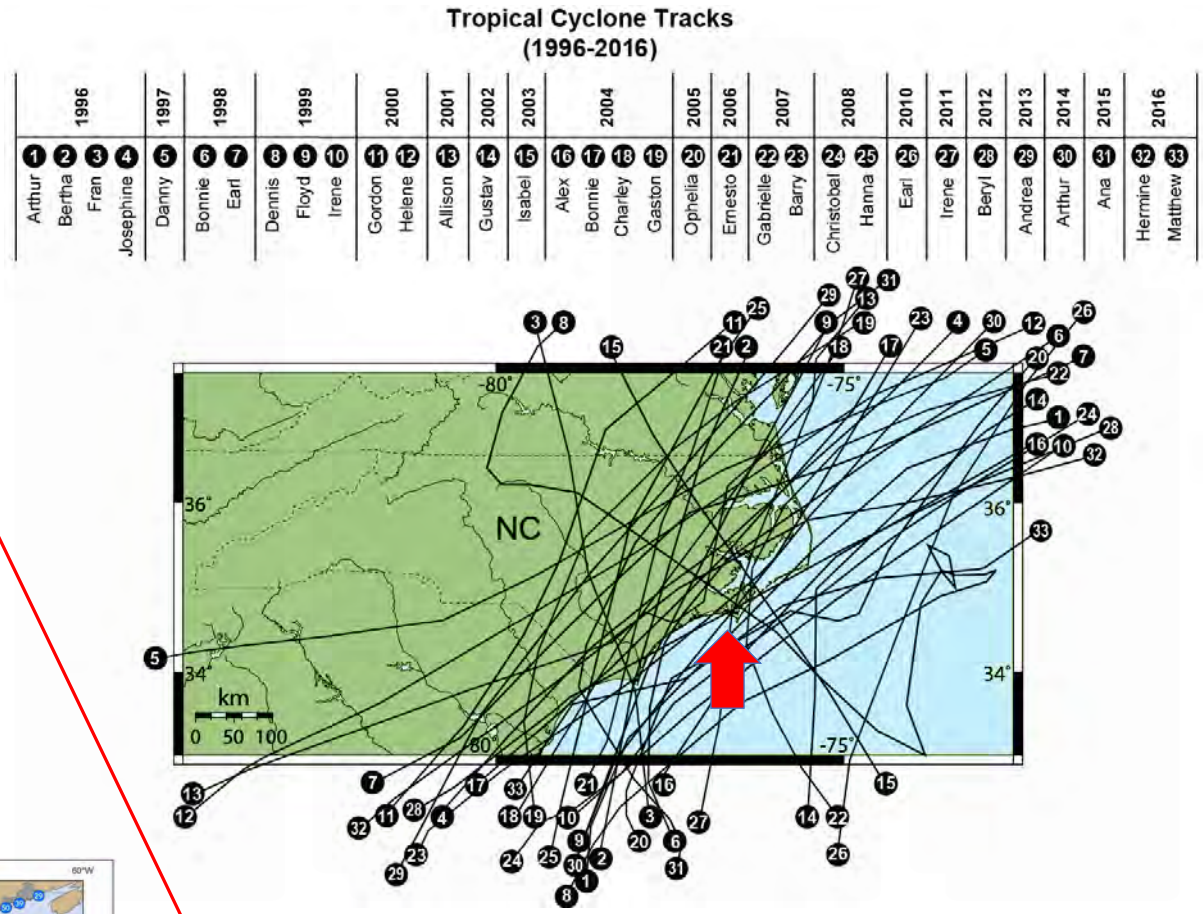
Coastal North Carolina, USA: A "magnet" for hurricanes/typhoons











Recent major cyclones and floods

Dennis & Floyd, Sept., 1999
Ernesto, Sept. 2006
Matthew, Sept.-Oct. 2015
Florence, Sept. 2018
Dorian, Sept. 2019

Paerl et al., 2018

Why the concern about tropical cyclones?

(Besides the obvious!)

Large Hydrologic perturbations

(lots of water, quickly, and persistent flooding in low-lying areas)

Increased Nutrient organic matter and contaminant inputs

Changes in sediment dynamics (transport, deposition, resuspension)

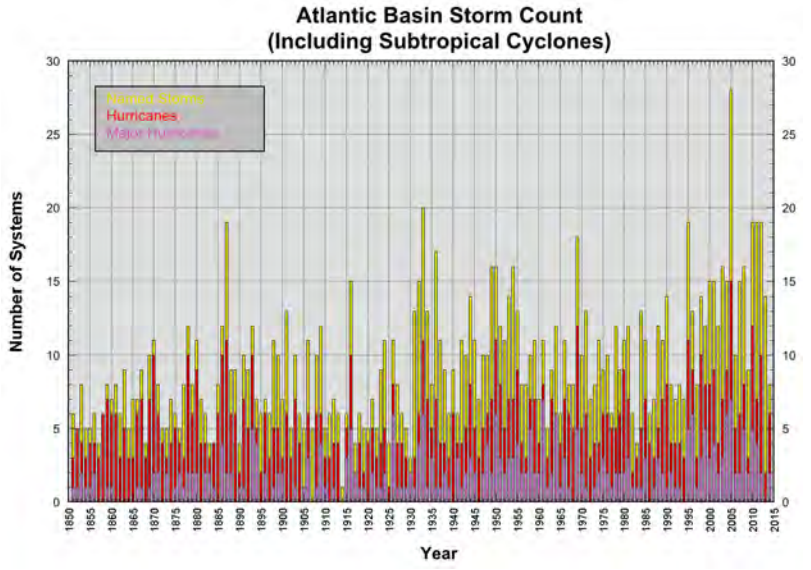
Biotic alterations (water quality, habitat, food webs)

Reason for concern……

"We appear to be in a period of elevated tropical cyclone activity"

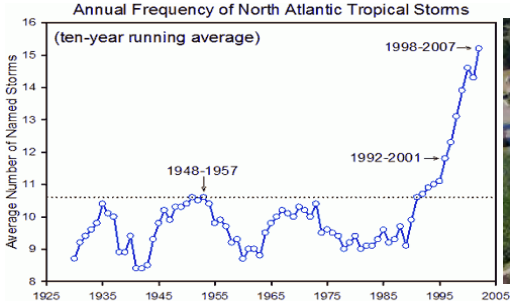
Emanuel 2005; Holland and Webster 2007; IPCC 2014; US Climate Change Report 2018

Hurricane Florence, Sept., 2018

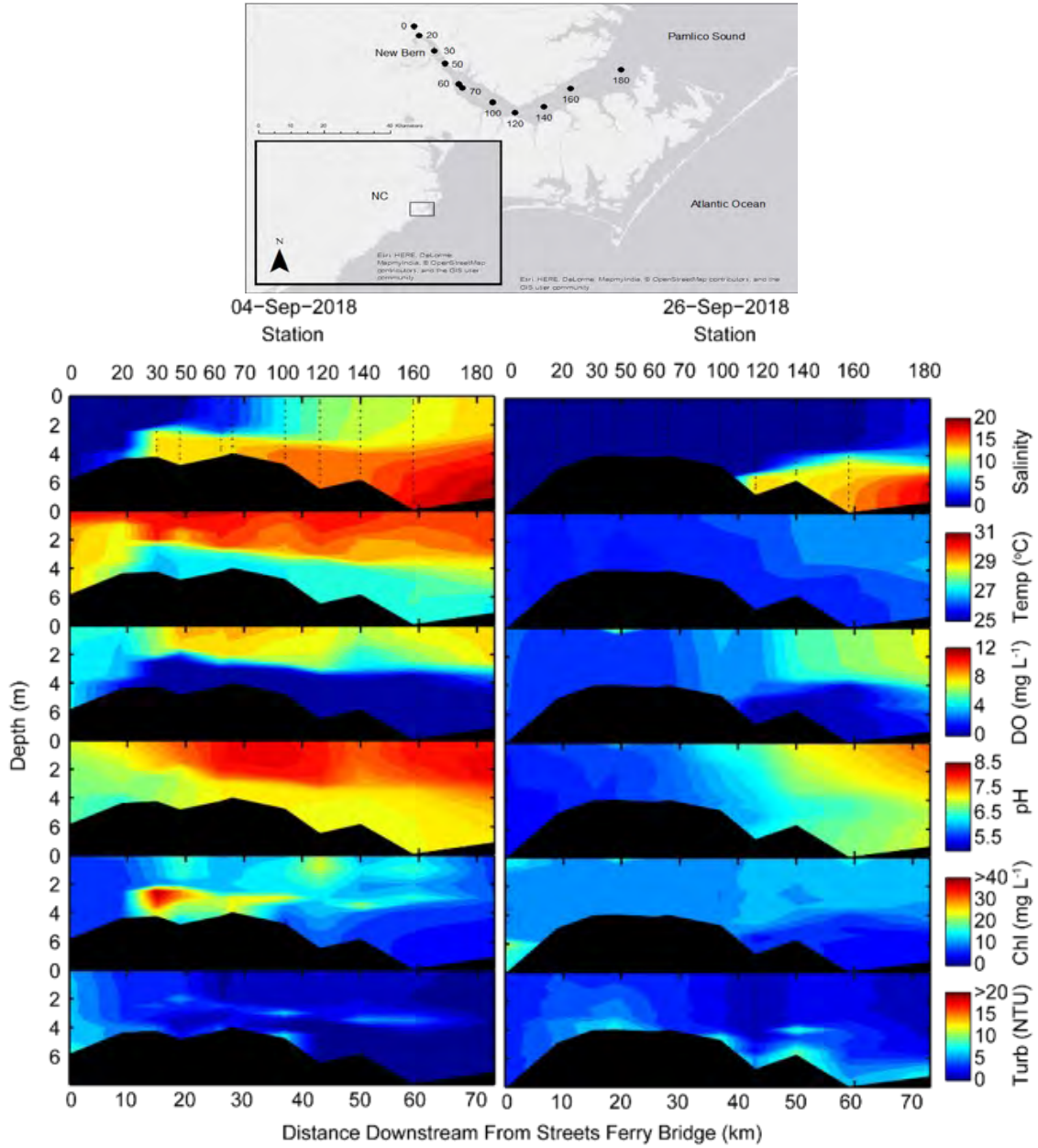


Albemarle-Pamlico Sound
Second largest estuary in USA

- Most important US SE fisheries nursery
- Drains over half of NC coastal plain and Southeastern VA
- >50 years of Ag and urban expansion accompanied by enhanced N and P loading
- Lagoonal estuaries; long residence times, susceptible to eutrophication
- Increasing frequency of tropical cyclones (34 in the past 25 years), and flooding



Impacts of hurricane Florence "freshet" on the Neuse River Estuary, NC.



http://paerllab.web.unc.edu/projects/modmon/

Nitrogen and phosphorus loading to the Neuse R. Estuary: How Important are tropical cyclones relative to "normal" hydrologic patterns ?

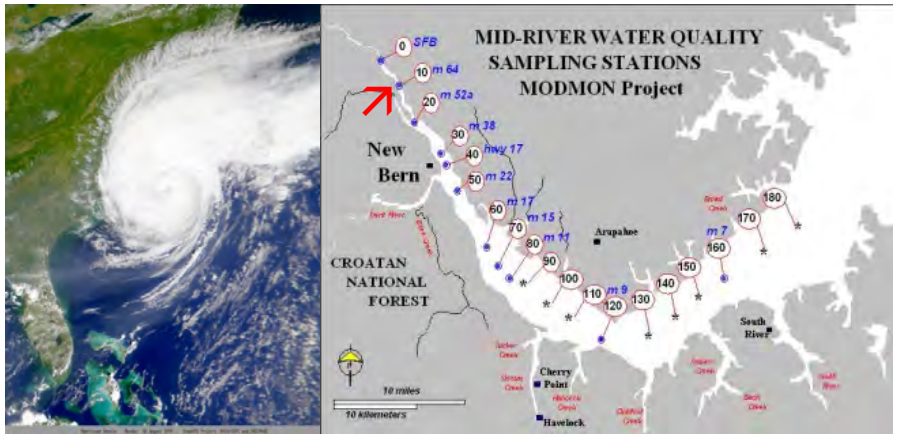
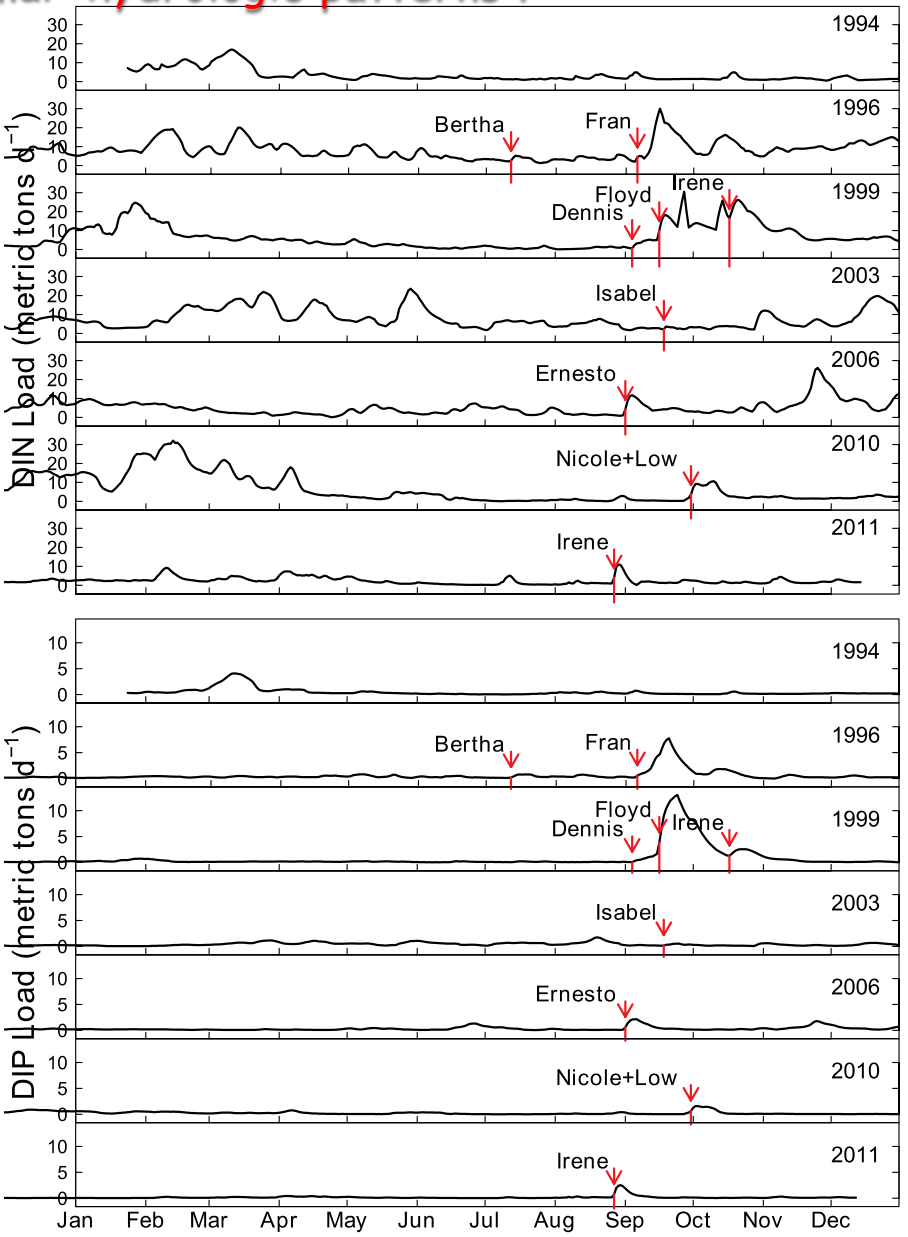


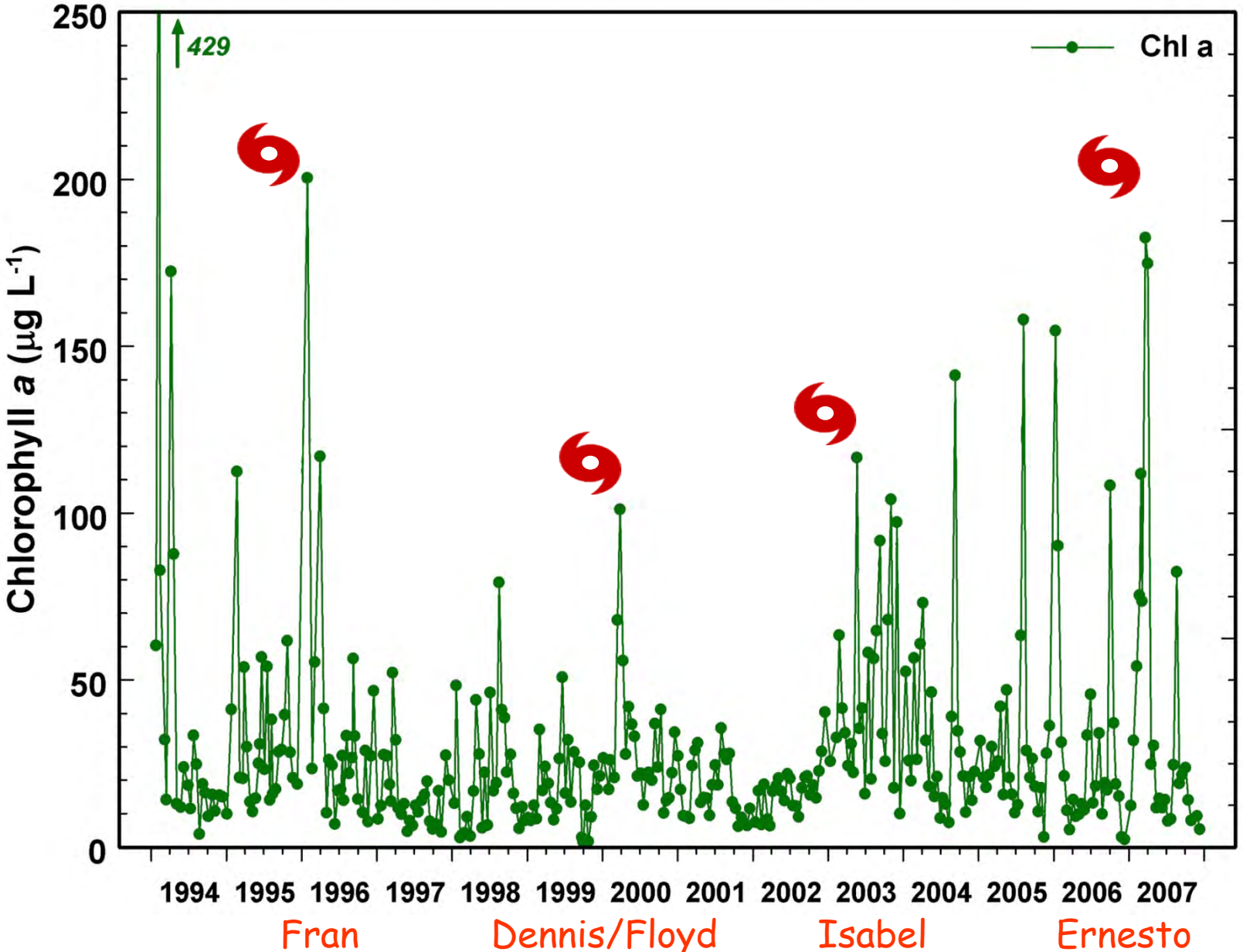
Table 4. Influence of "wet" storms on long-term (1996-2016) material loads to the Neuse River Estuary.

Parameter	Percent of Long Term Load During Storm Flows	Percent Increase Over Baseline Due to Storms
Water	13.9	15.5
TN	11.6	12.6
DIN	7.2	7.5
DON	16.0	18.3
PN	16.0	18.2
TP	21.5	25.7
SRP	26.0	32.8
DOC	21.2	25.6
POC	17.0	19.6
DIC	14.1	15.7

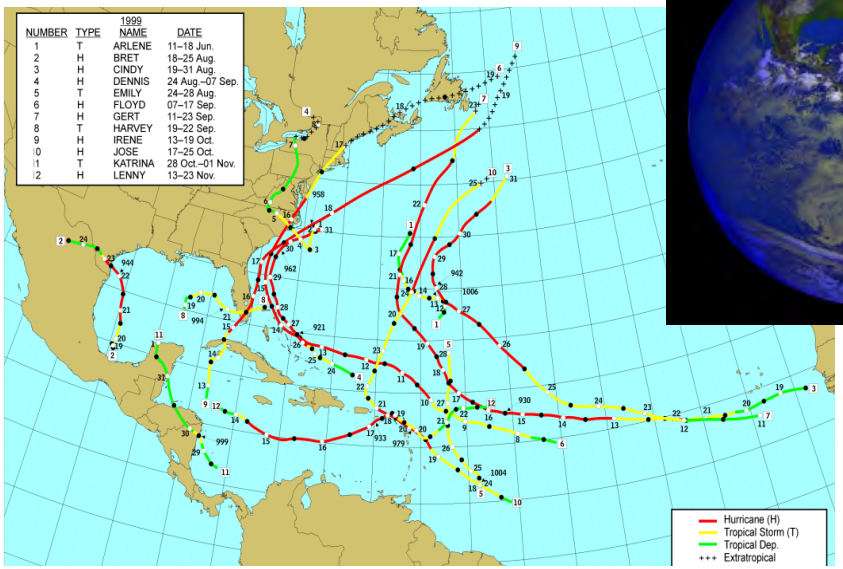


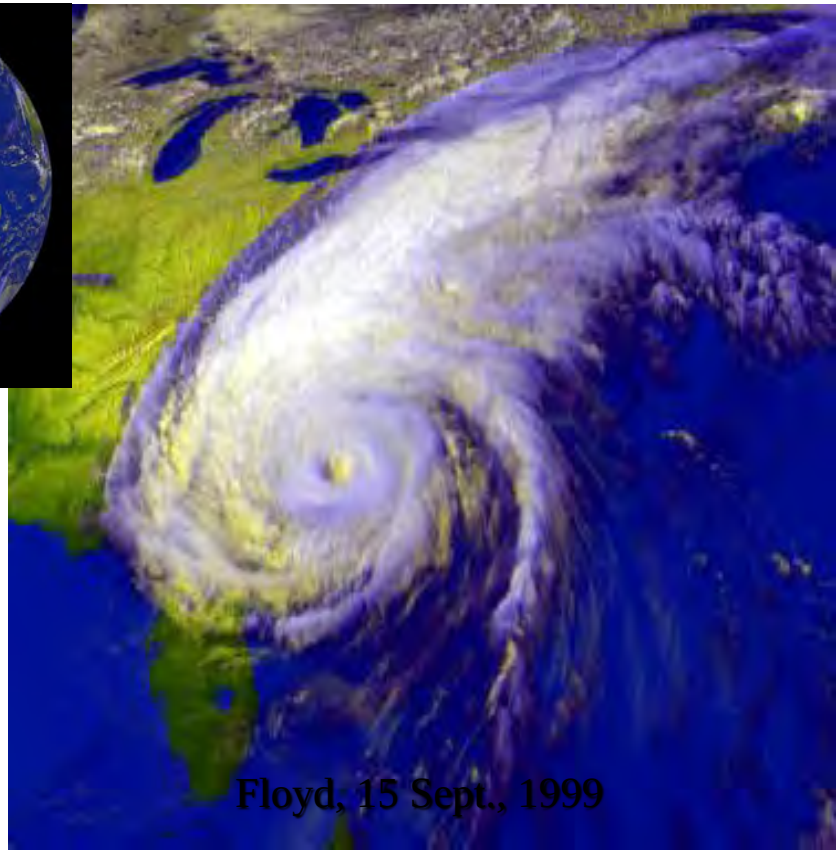
Hall et al., 2013; Peierls et al., 2012; Paerl et al., 2014, 2018

Major hurricanes/tropical storms & phytoplankton biomass (Chl *a*) responses in the Neuse R. Estuary, NC



The Hurricanes of 1999: What Happened?





- 3 SS-scale 3 hurricanes (Dennis, Floyd & Irene) within 6 weeks
- Record rainfalls in Pamlico Sound Basin: 12-h rainfall totals >> 100-yr.
- 50-500 year floods in PS watershed
- PS Received annual water and N loads in about 1.5 months

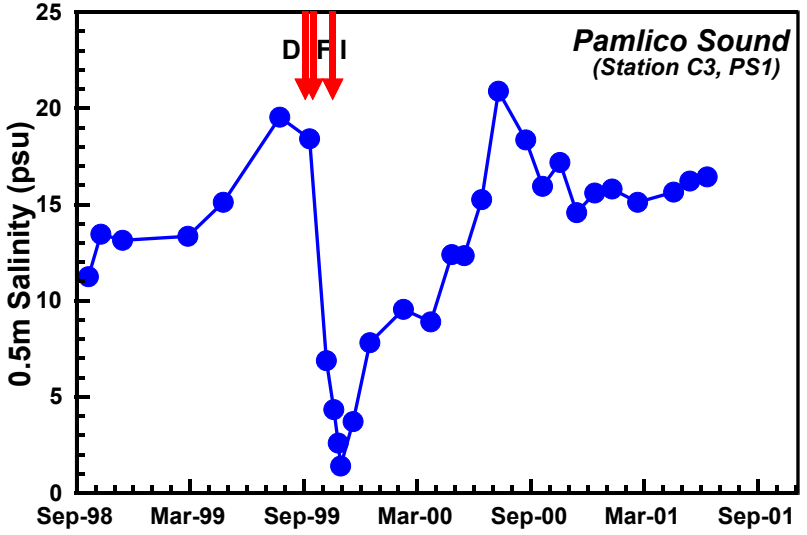
Ecosystem Impacts

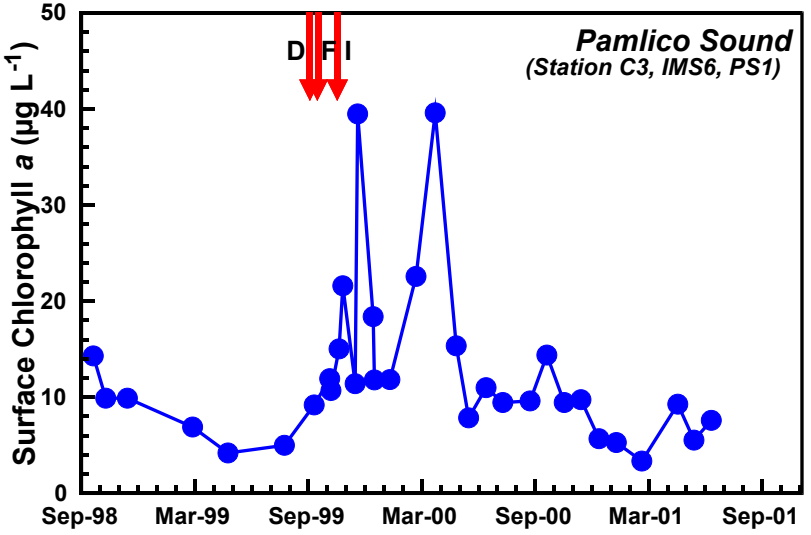
Pre-hurricane

Post-Floyd, September 23, 1999

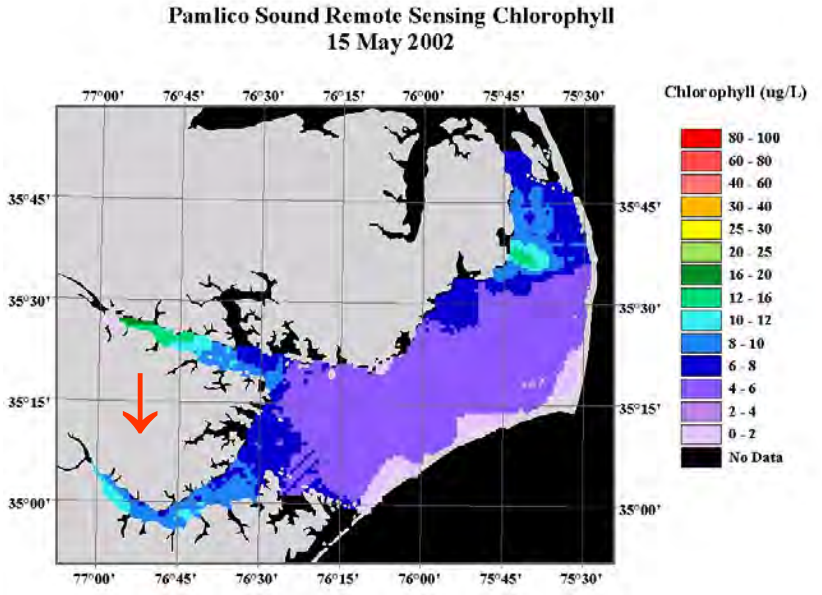
Hurricanes Dennis, Floyd & Irene ('99)

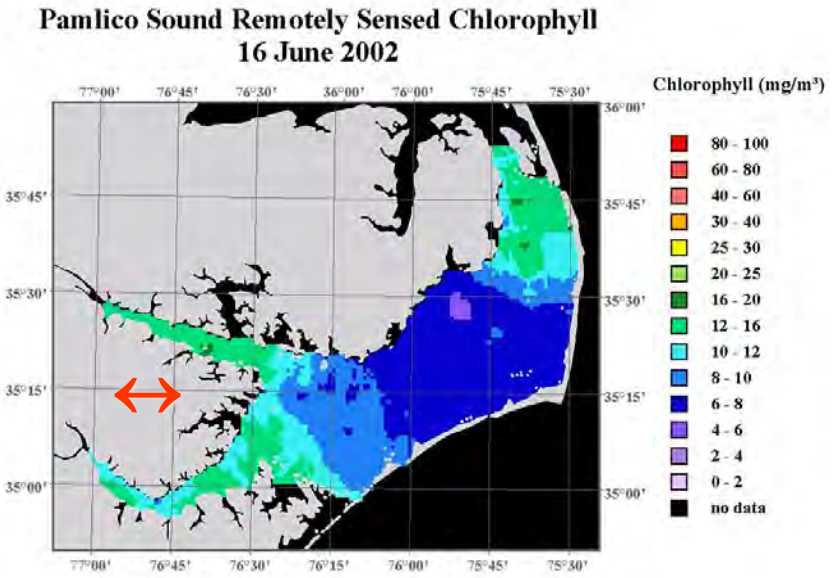
Salinity and Chlorophyll *a* responses in the Pamlico Sound

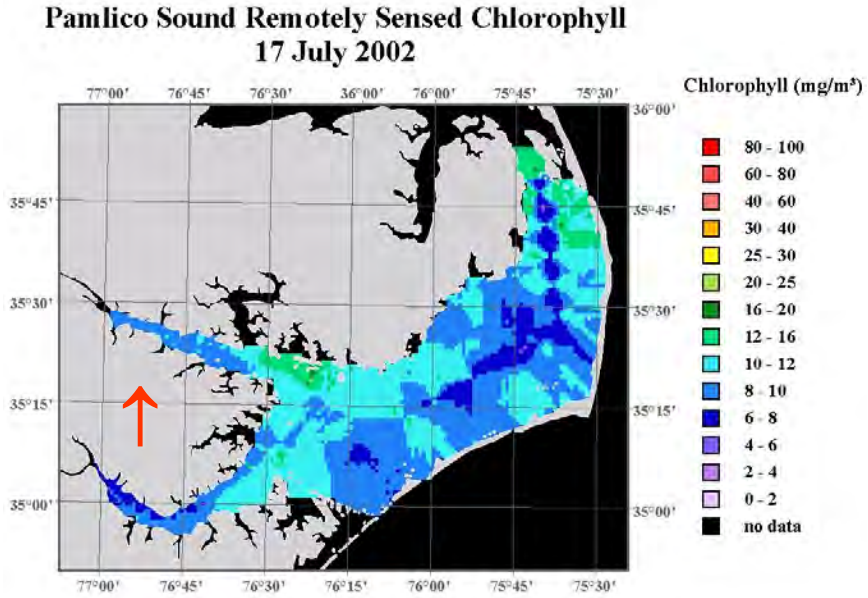


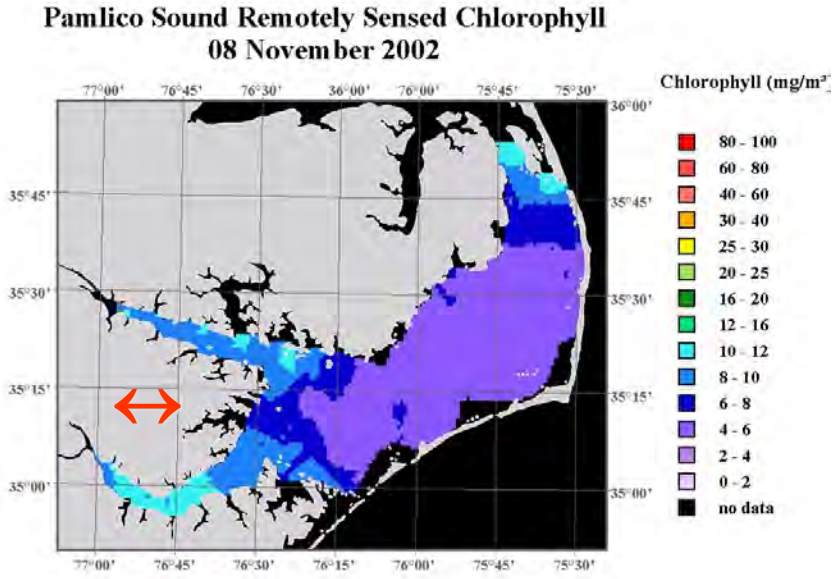


Freshwater Discharge and flushing effects on algal production (Chl *a*) in Pamlico Sound, NC



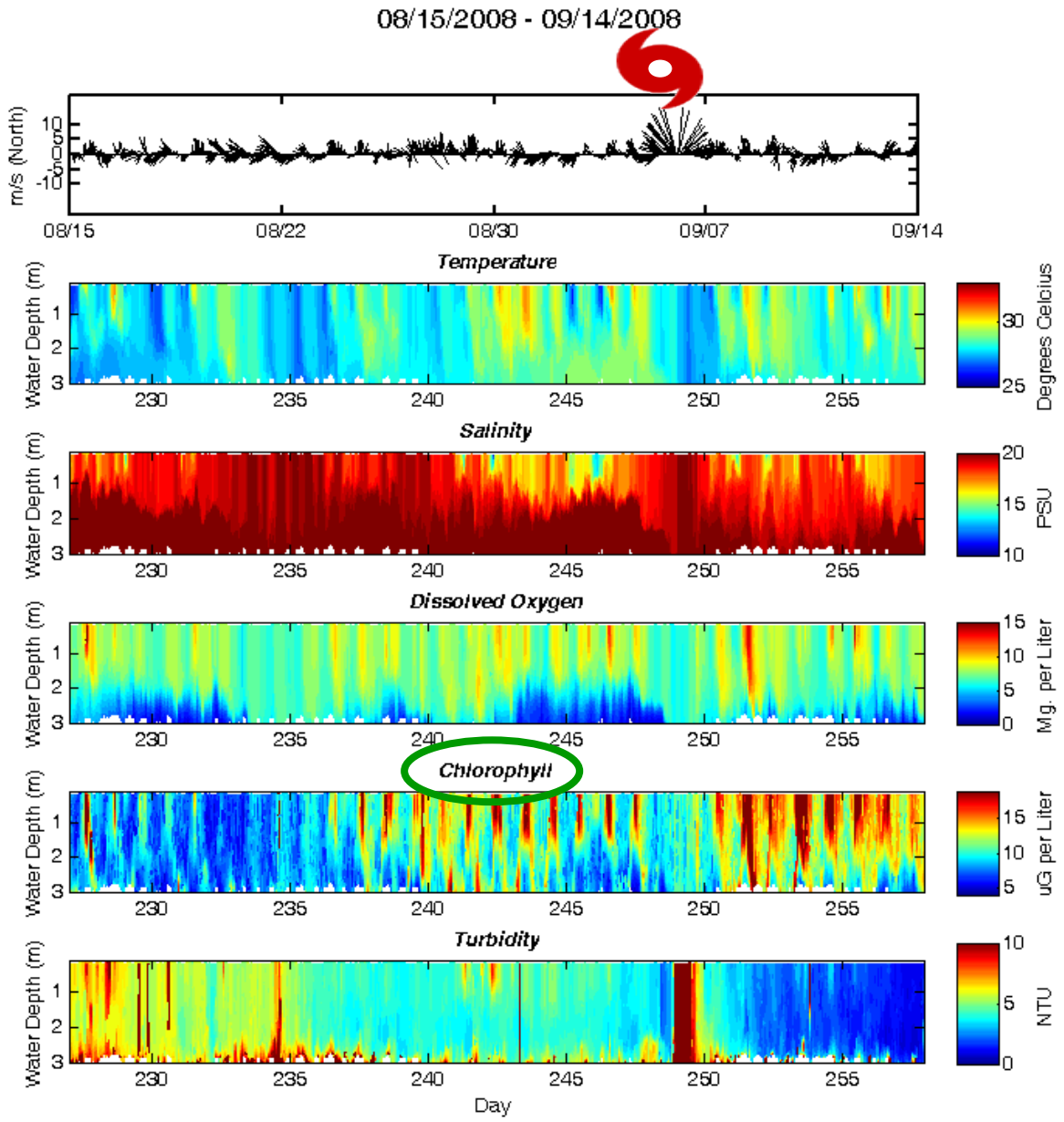


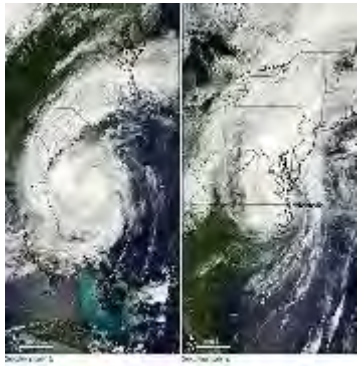




Flow: high↑, low↓, moderate↔

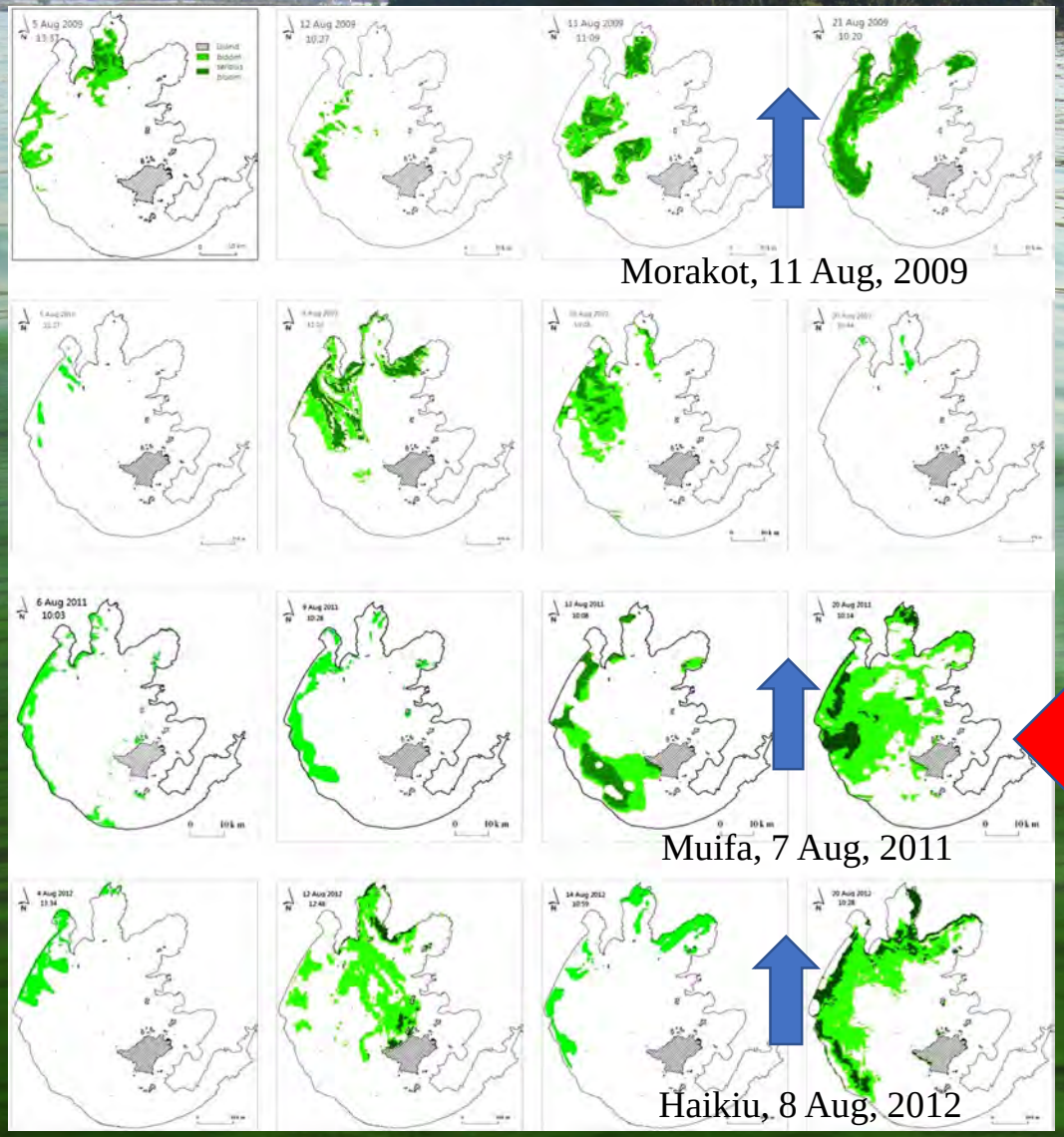
Impacts of Tropical Storm Hanna (8/15/08 – 9/14/08) on The New River Estuary, North Carolina, USA





Impacts of Typhoon passages on cyanobacterial blooms in Lake Taihu, China, based on MODIS data

(Zhu et al., 2014)

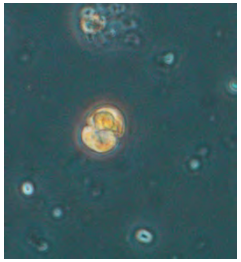


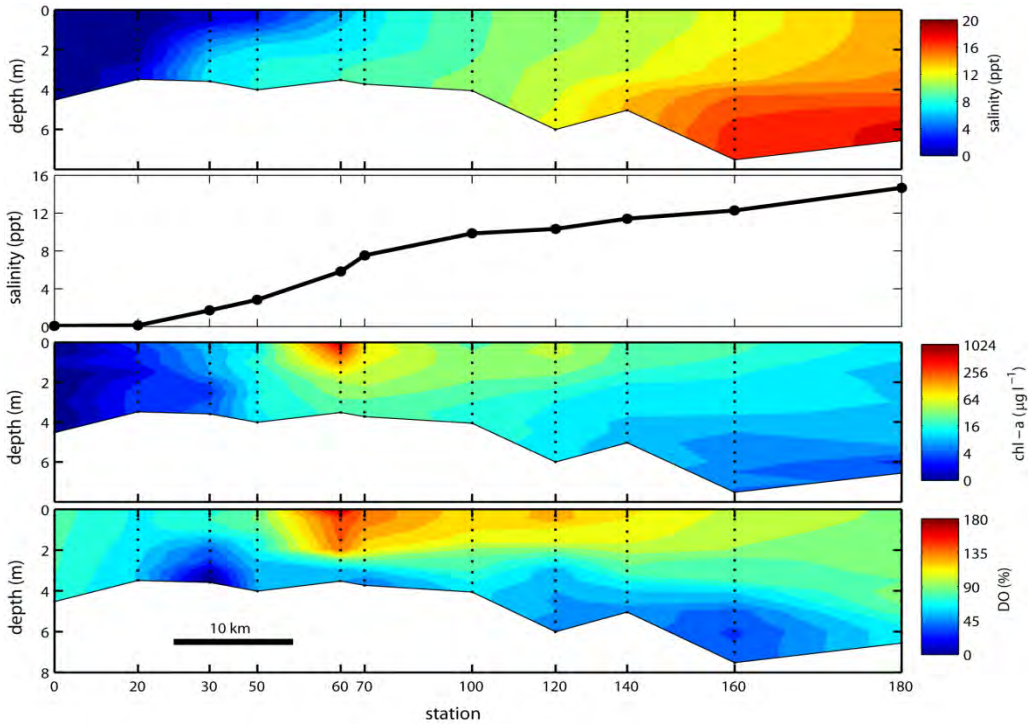
Morakot, 11 Aug, 2009

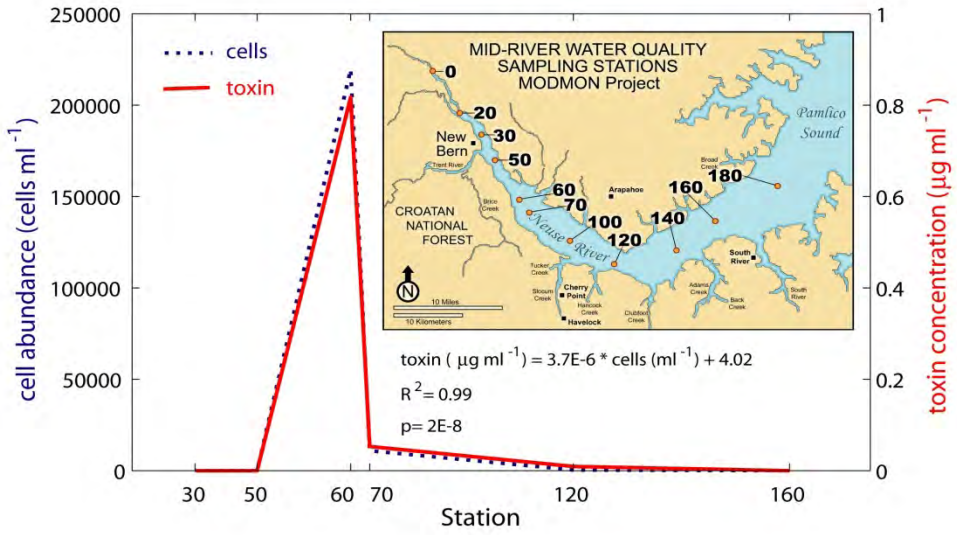
Muifa, 7 Aug, 2011

Haikiu, 8 Aug, 2012

A specific example: toxic dinoflagellate (*Karlodinium)* bloom following nutrient-enriched runoff from Tropical Storm Ernesto, Oct. 2006







- **Runoff associated with Ernesto contained nutrient load and set up strong salinity stratification**

- **Favorable light and temperature created ideal conditions for an algal bloom.**

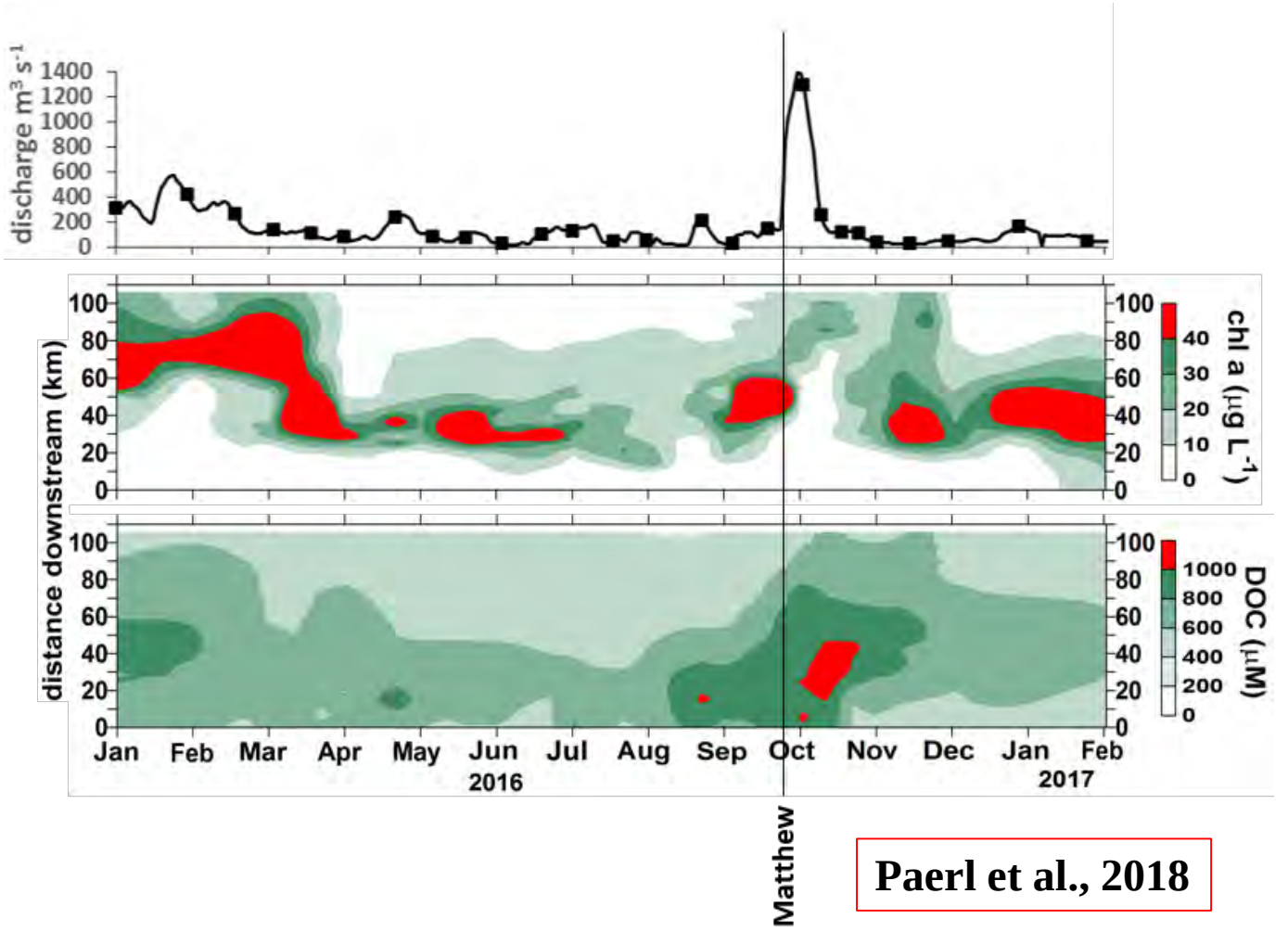
- **Near-surface stratification was favorable for motile dinoflagellates; *Karlodinium* prefers these conditions in fall.**

Hall et al. 2008

"Pulse-shunt" (Raymond et al. 2016) phenomenon after Hurricane Matthew's (Fall 2016) "500 year" floodwaters impacted the Neuse River Estuary, NC. This caused a rapid "shift", where phytoplankton production (as chlorophyll a) was flushed from the system and replaced by watershed-derived organic matter (as DOC) inputs in response to Matthew's floodwaters. However, notice rapid Chl a response afterwards.

Before

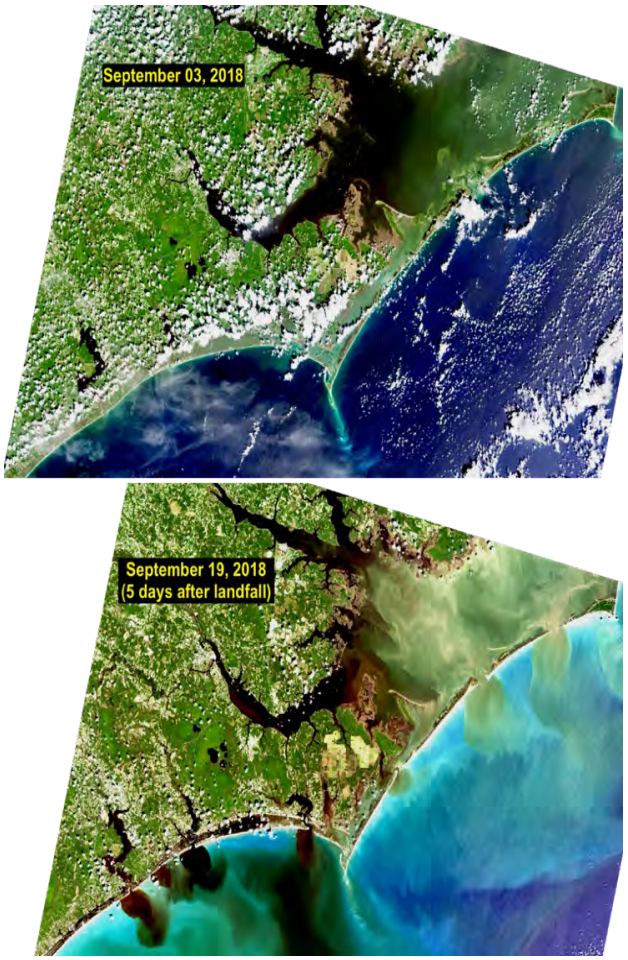
After

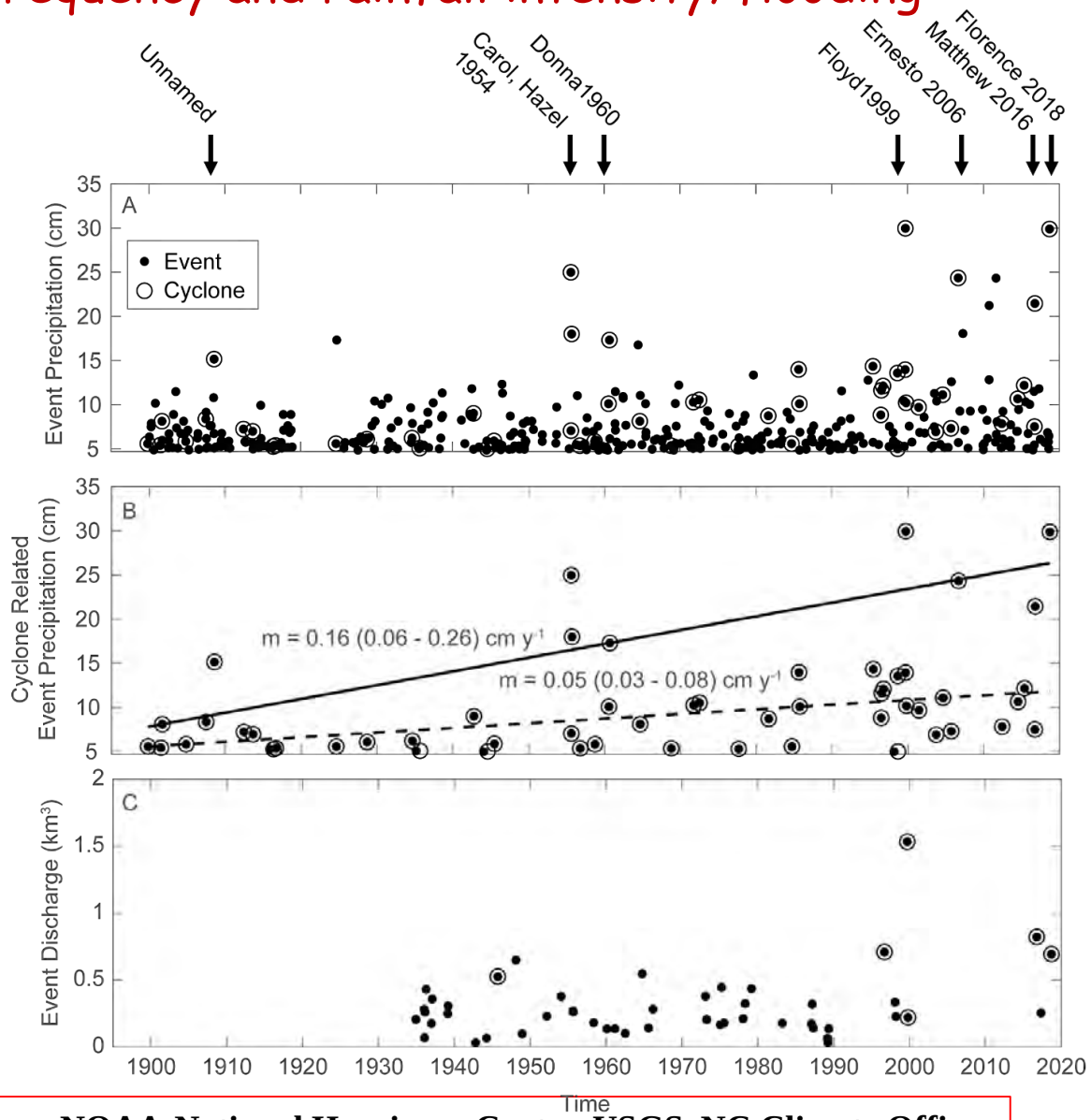


Paerl et al., 2018

The future??

We appear to be experiencing a "new normal" with regard to tropical cyclone frequency and rainfall intensity/flooding





Paerl et al., 2019. Data sources: NOAA-National Hurricane Center, USGS, NC Climate Office

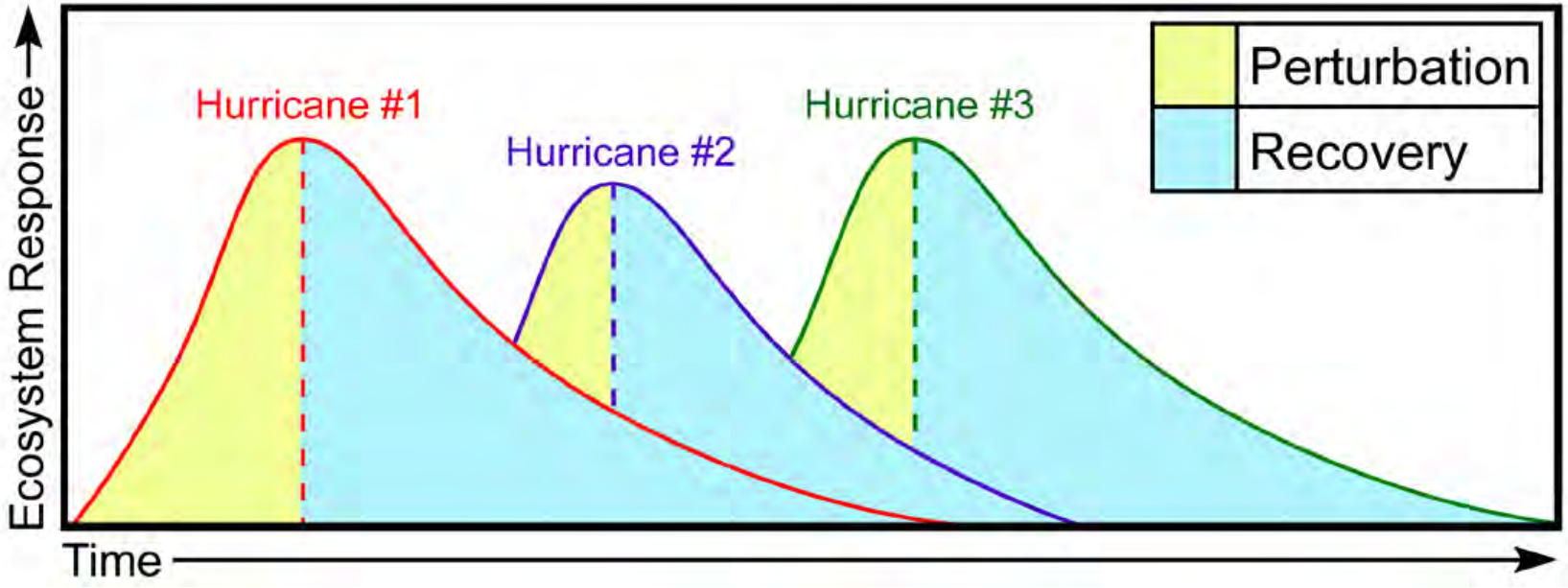
Increased frequency of Atlantic hurricanes over the next 10-40 years?

Goldenberg et al., 2001, Webster et al. 2005; Holland and Webster 2007

Increase in "extremeness" and scales of storm events?

Emanuel 2005; Wuebbles et al.,2014; IPCC 2014; US Climate Change Report 2018; Paerl et al.,in review

Multi-annual ecological effects and recovery?



Implications and what can we do to best manage impacts

- Storm-driven N (and P) loading is increasing in coastal waters….promoting more algal blooms, hypoxia, fish kills, habitat decline

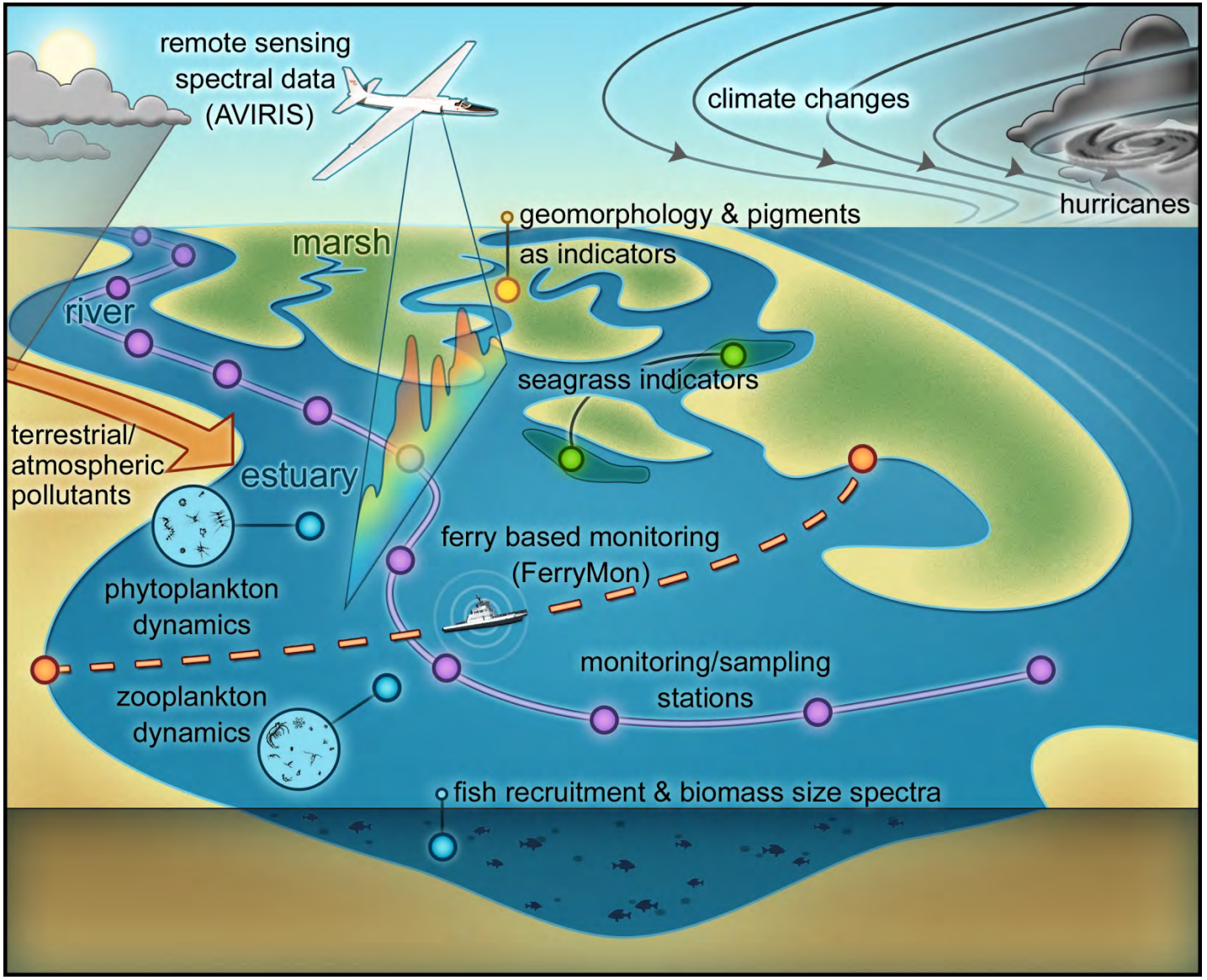
- We're experiencing a "new normal" in tropical cyclone frequency, rainfall intensity and flooding, driven by ocean warming and sea level rise.

- What can we do about it? Retain nutrients, sediments/organic matter and other pollutants in watershed (riparian buffers, no-till Ag, stormwater retention, less & timely application of fertilizers). Reduce emissions of greenhouse gases (CO_2, methane, NO_x), and make plans for long-term, sustainable development.

- Immediate Needs: Tools (e.g.remote sensing, continuous water quality monitoring) to capture events/impacts over relevant scales and adaptive nutrient management in response to climatic changes and extremes

Thanks for attending!

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # 82667701



Special Thanks to:

Lower Neuse Basin Assoc./Neuse River Compliance Assn.

National Fish & Wildlife Foundation

Water Resources Research Institute

NC Sea Grant

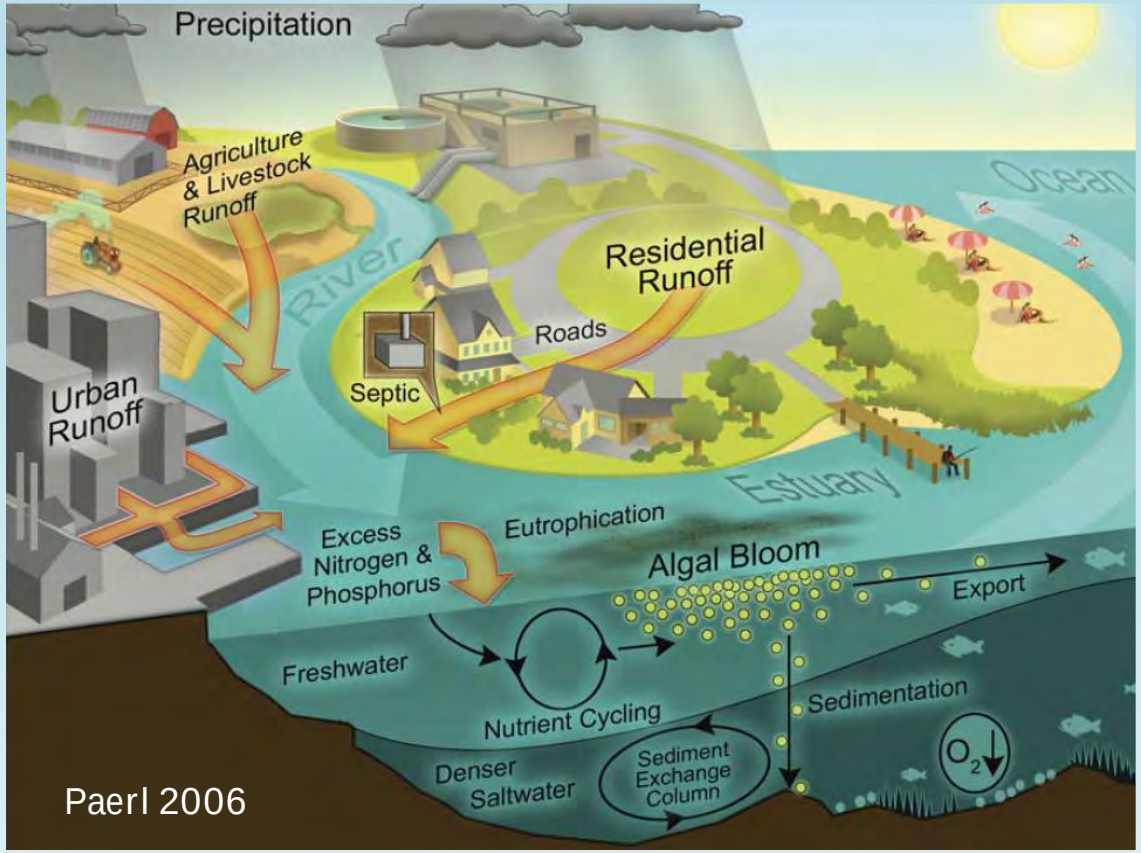
http://paerllab.web.unc.edu

Nitrogen Inputs Along our Changing Coasts: Evaluating the Role of Onsite Wastewater in an Era of Climate Change

Michael O'Driscoll, Associate Professor, Dept. of Coastal Studies; Assoc. Director of ECU Water Resources Center, East Carolina University
Charles Humphrey Jr., Associate Professor, Environmental Health Sciences, East Carolina University
Jane Harrison, Coastal Economics Specialist, NC Sea Grant

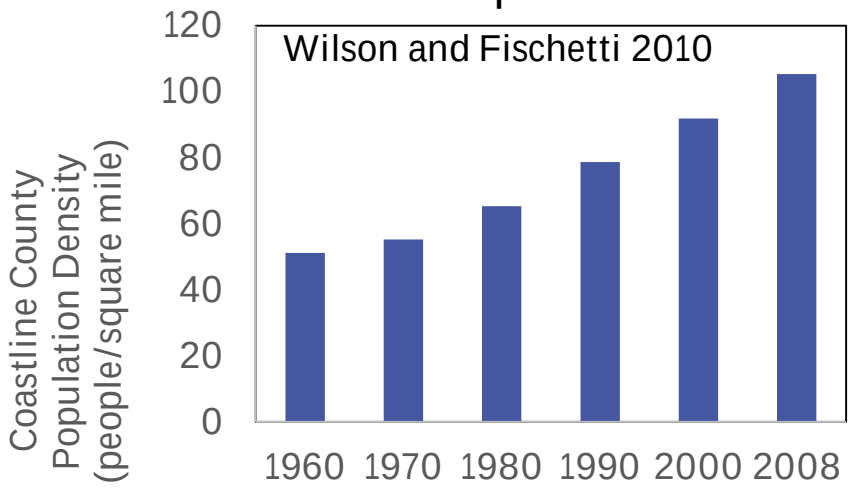
Nutrient Challenges in Coastal NC

- Excess nitrogen (N) can lead to:
  - blue baby syndrome, potential cancer links, nuisance odor and taste issues, algal blooms, eutrophication, & fish kills
- N sources to the coast include urban runoff, municipal wastewater, atmospheric deposition, fertilizer, & animal waste.
- Onsite wastewater N inputs are often underestimated - difficult to assess because they are often discharged to the subsurface.
- Wastewater has been shown to be a dominant N source in various coastal watersheds (Valiela et al. 1997, Carmichael et al. 2004, Shuler 2016, Iverson et al. 2016).
- More information is needed to understand onsite wastewater N inputs in coastal areas.

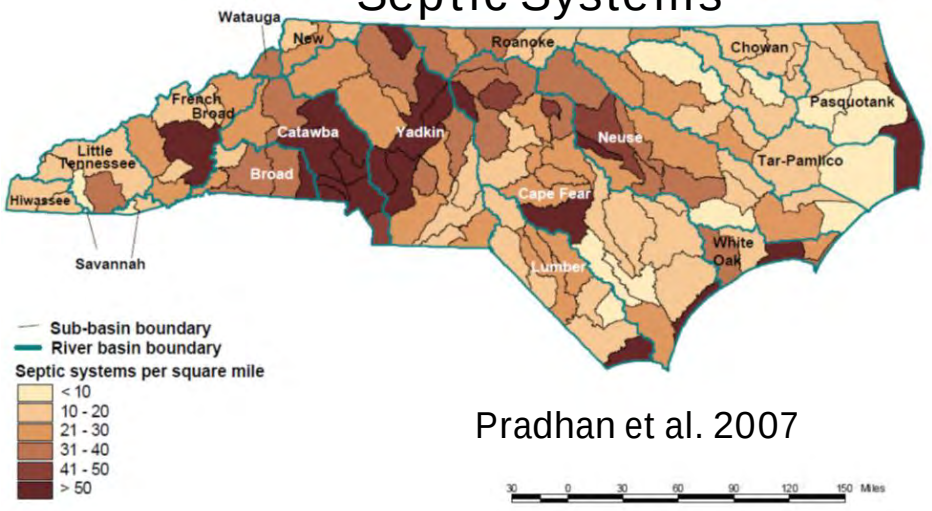


Many NC Coastal Regions are Experiencing MORE…..

People



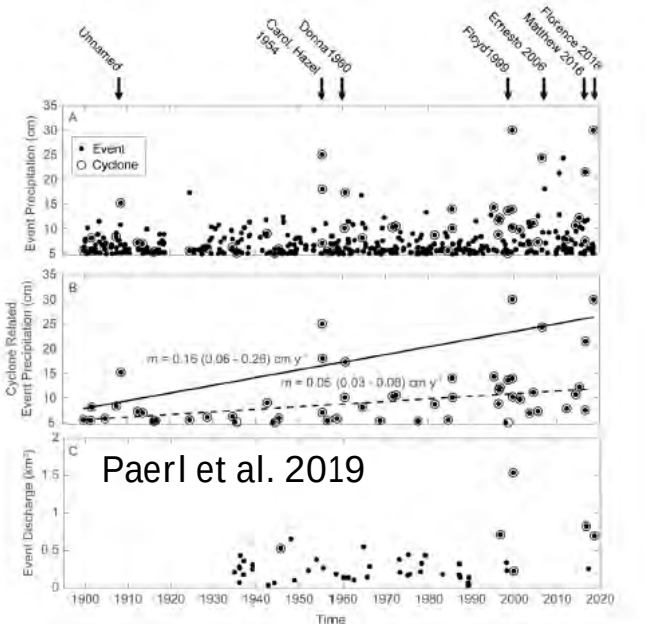
Septic Systems



Pradhan et al. 2007

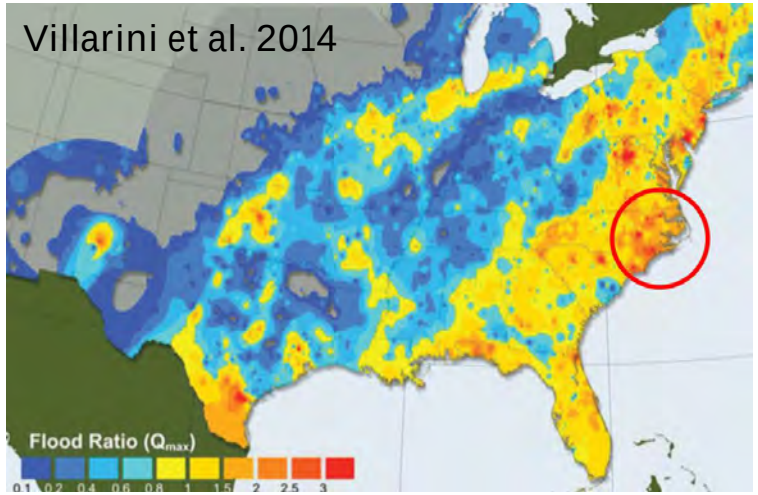
Nutrients

Extreme Precipitation Events

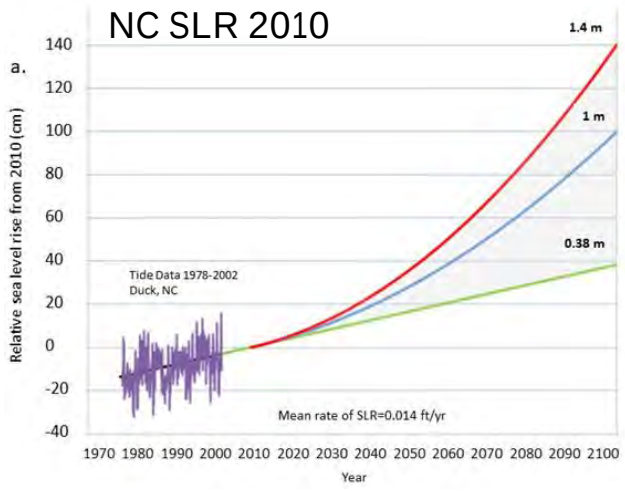


Paerl et al. 2019

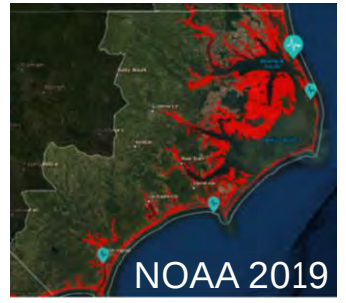
Tropical Storm Flooding



Sea Level Rise



Sunny Day Flooding



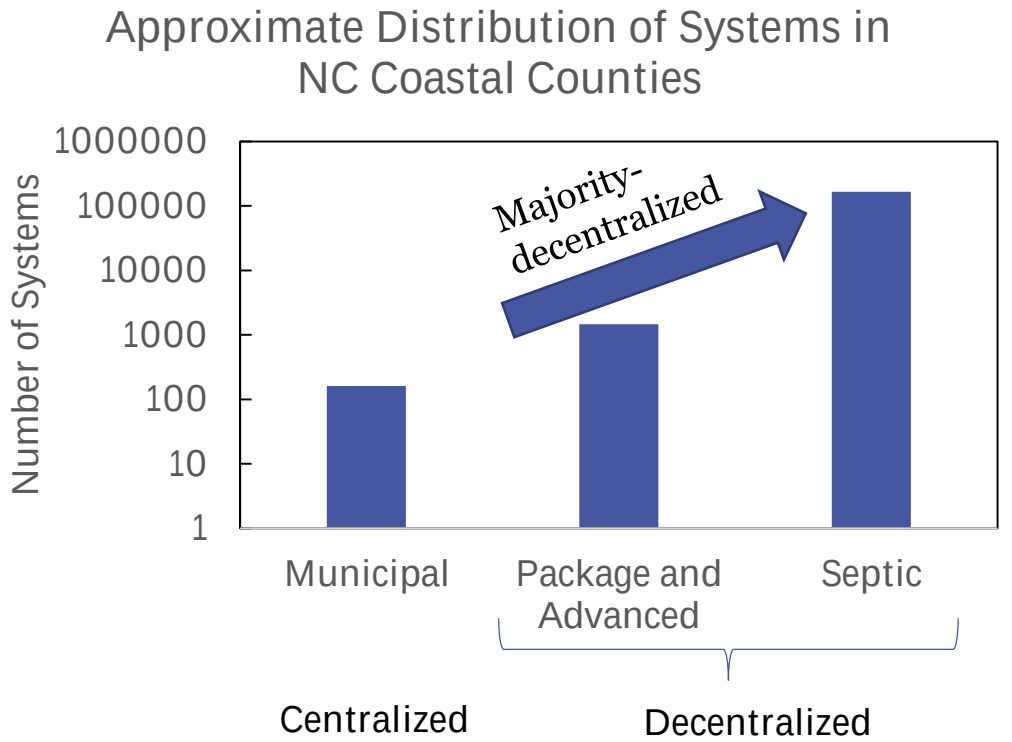
More Isn't Always Better!

http://www.trootrac.com/blog/bigger-isnt-always-better/

Wastewater Treatment in Coastal NC

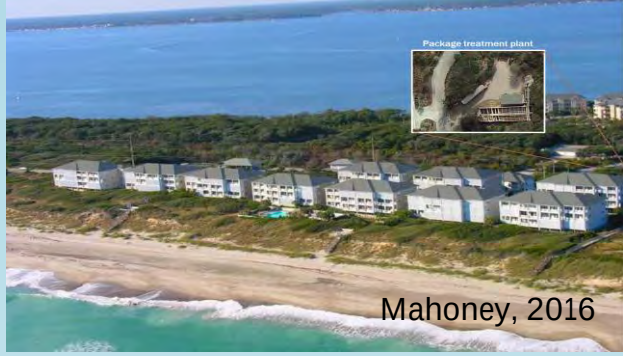
- Decentralized (onsite) - Rural and suburban areas:
  - Septic-tank disposal (onsite wastewater treatment) (conventional, cluster, and advanced)
  - Package treatment plants (PTPs) and advanced systems
    - wastewater treatment facilities that are designed to treat onsite wastewater for small communities, commercial developments, and individual properties
  - Many of North Carolina barrier island and beach communities utilize PTPs (OBX, Bogue Banks, etc.)

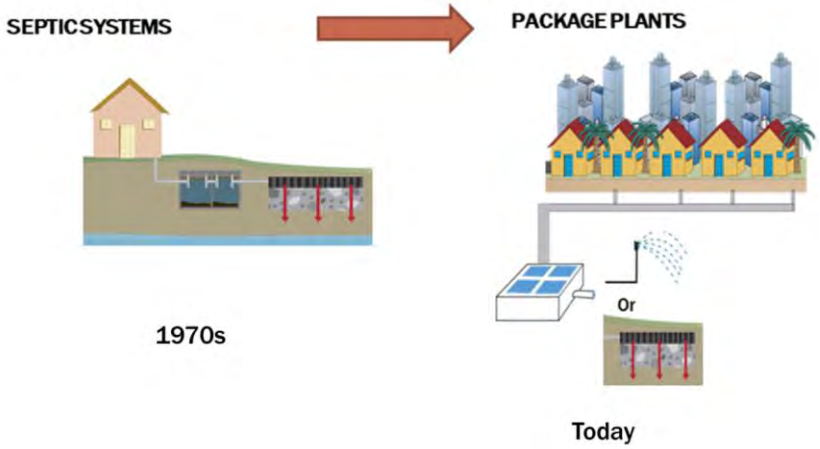
- Centralized - larger communities and most urban areas
  - Sewered and centralized wastewater treatment (municipal treatment plants)



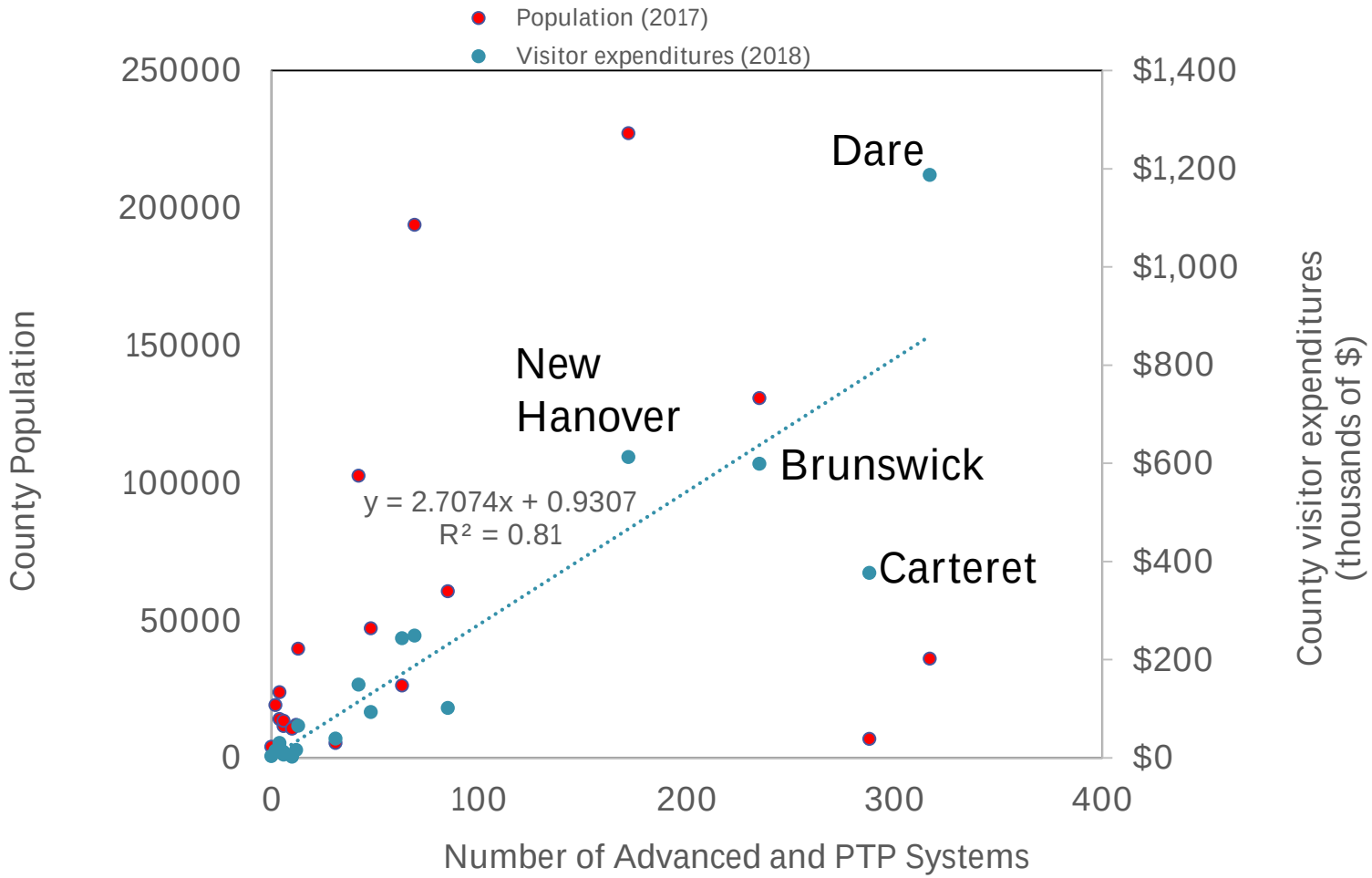
Package Treatment Plants (PTP)

Package treatment plants (PTPs) are facilities designed to treat onsite wastewater for small communities, commercial, and residential developments. PTPs are being used in a growing number of coastal communities.





- Up to 200,00 gallons/day
- > 1000 systems in Coastal NC Counties
- Began permitting in early 1970s
- Helpful in tourist areas where there are large changes in seasonal water use and wastewater generation

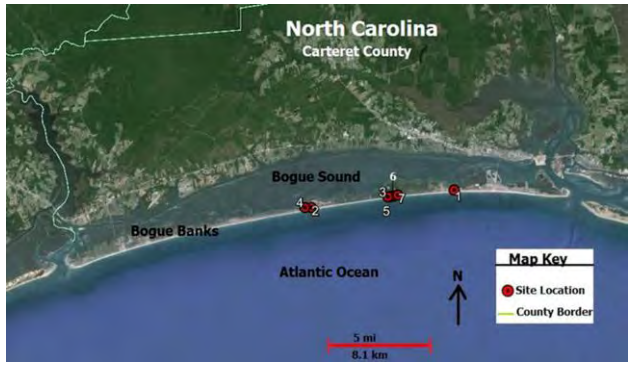


A Growing Year-Round Population and Seasonal Tourism Can Increase Water Use and Wastewater Generation for Coastal Communities

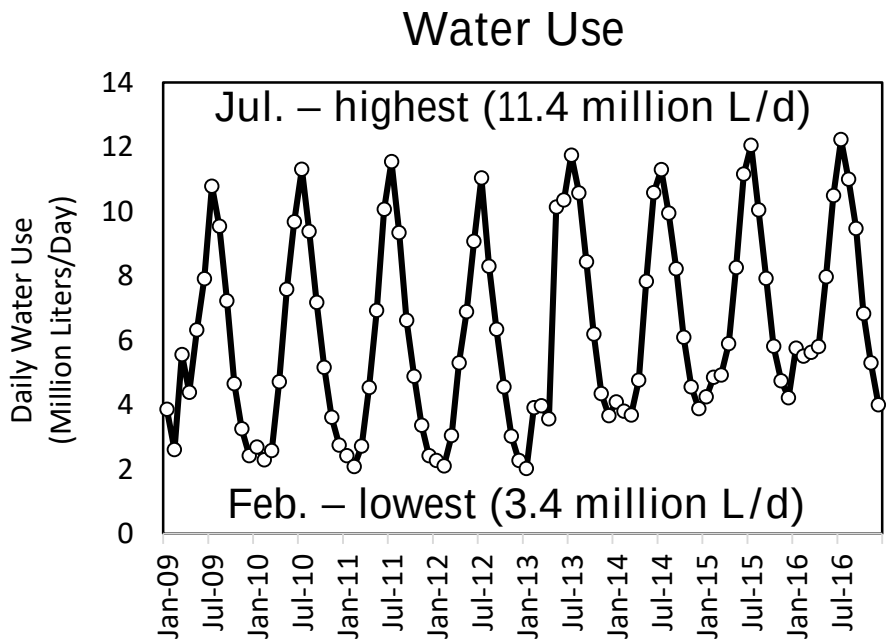
Environmental Management
https://doi.org/10.1007/s00267-019-01201-7

Coastal Tourism and Its Influence on Wastewater Nitrogen Loading: A Barrier Island Case Study

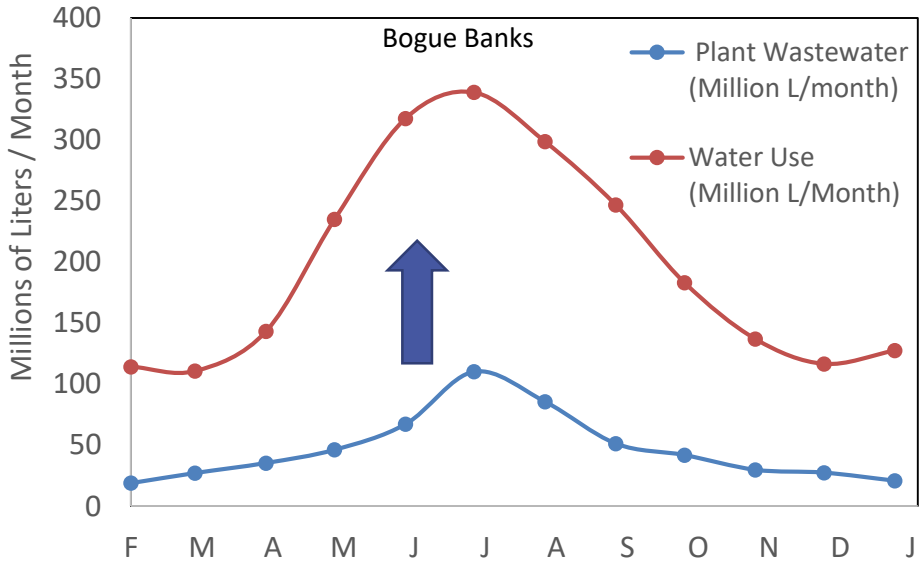
Michael O'Driscoll[1] · Eban Bean[2] · Robert N. Mahoney[3] · Charles P. Humphrey Jr.[4]



PTP Site Locations (Bogue Banks, NC)



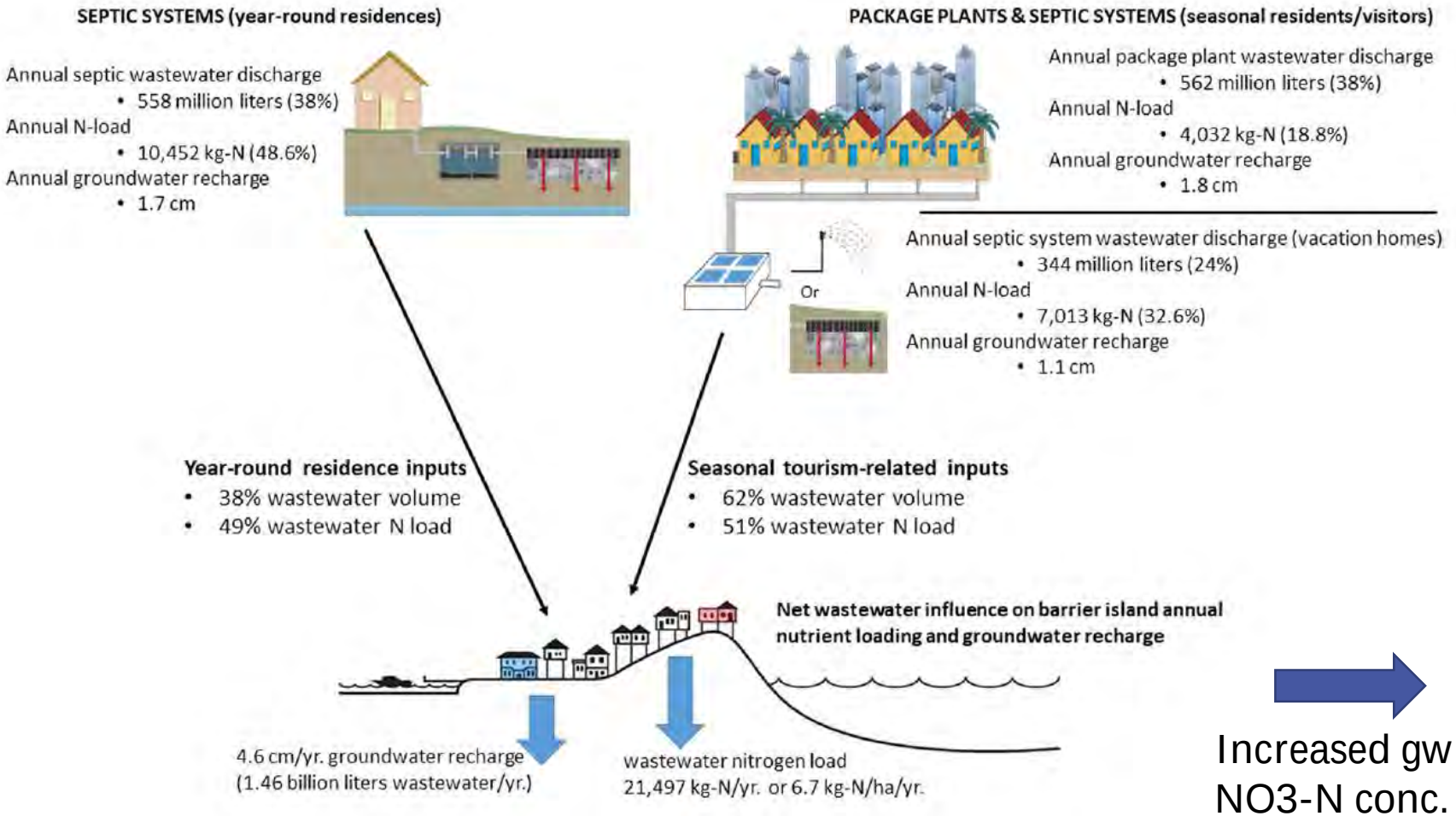
- ~3 x greater water use in July vs. Feb.*



- Increased summer water use-> package plant wastewater discharge
- Summer wastewater discharges (June-August) ~47% annual PTP ww

*Water use data from Bogue Banks Water Corp. Data, NC DEQ

Seasonal Coastal Tourism can Increase N Loading

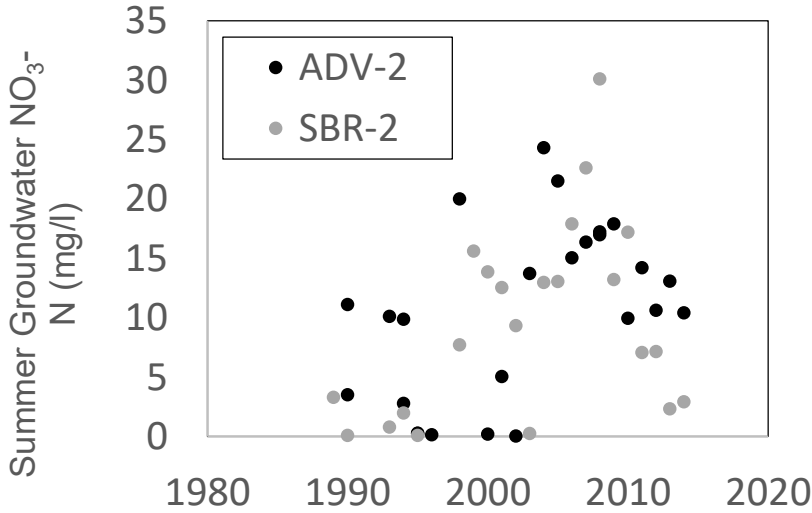


O'Driscoll et al. 2019

Bogue Banks, NC

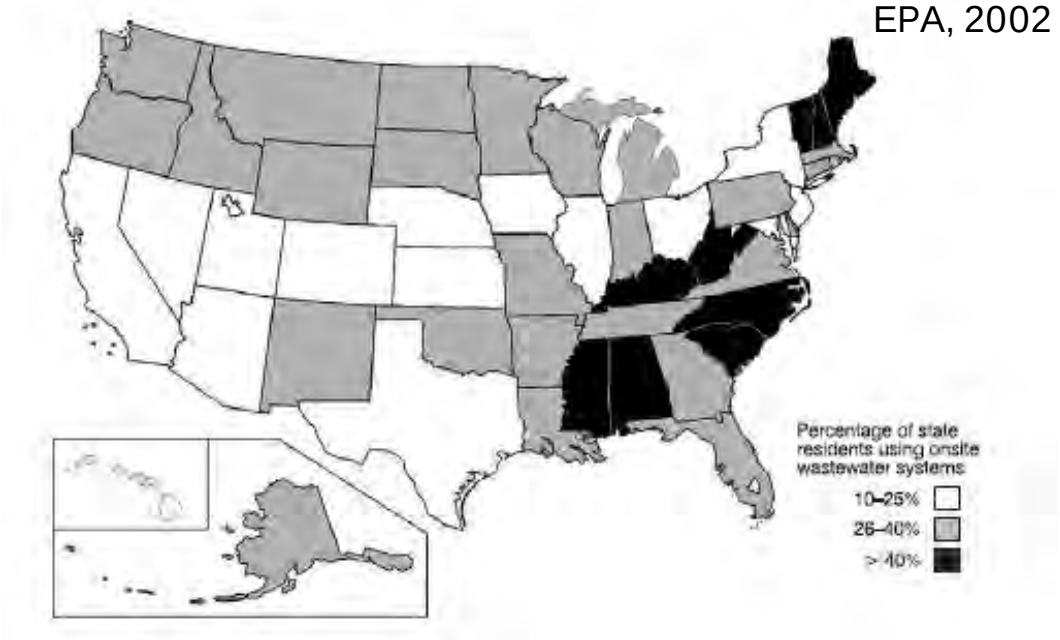
- ~1/2 of wastewater N load to aquifer comes from tourist/seasonal visitor related inputs
- ~ 40 PTP systems active on Bogue Banks

Increased gw NO3-N conc.

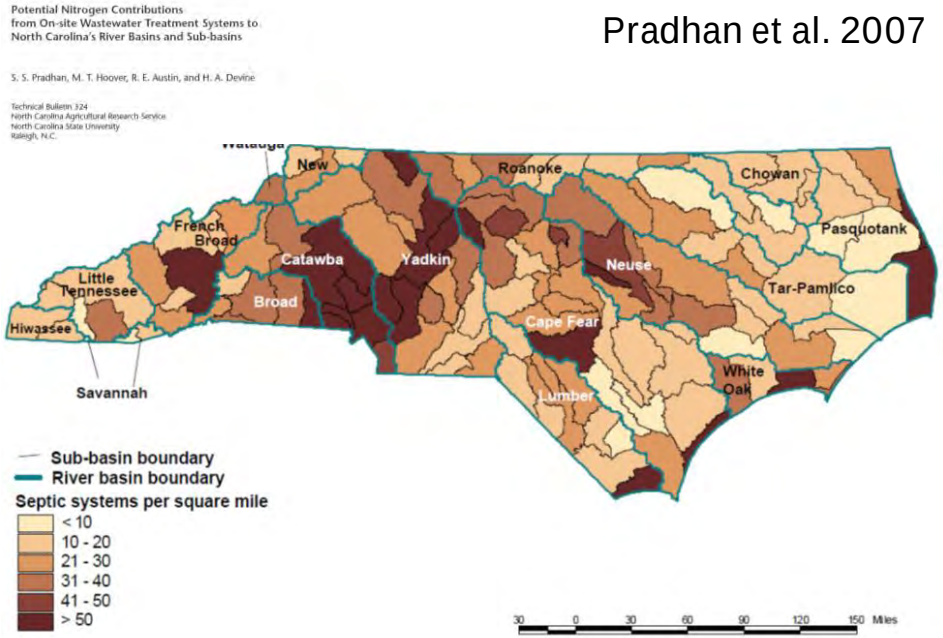


NC Reliance on Onsite Wastewater Treatment & Disposal

EPA, 2002

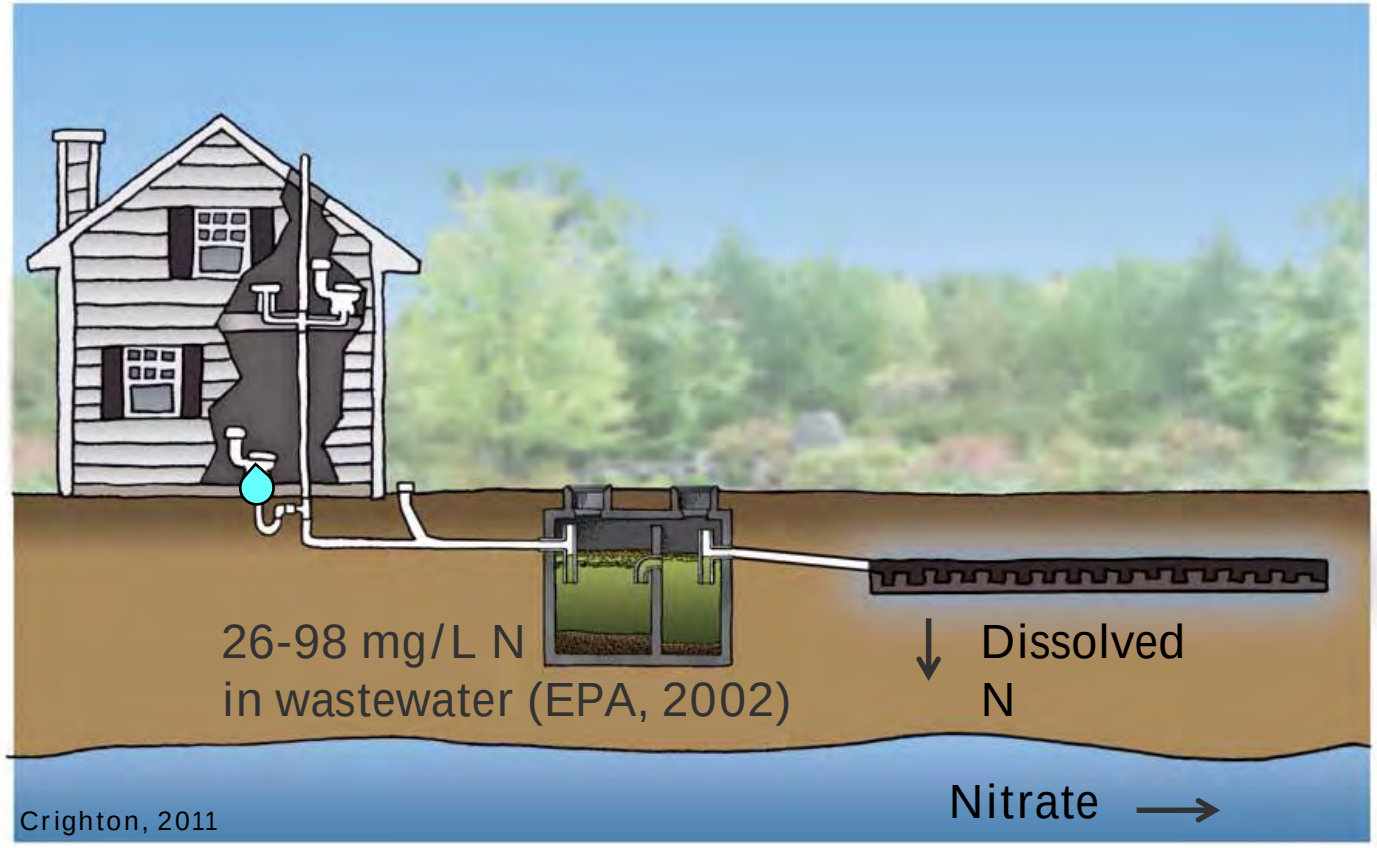


Pradhan et al. 2007



- North Carolina relies more heavily on septic systems, particularly in the Coastal Plain
- North Carolina has the highest percentage of residences served by onsite wastewater treatment (or septic) systems (OWTS) in the southeastern U.S. (48.5%) and fourth highest in the country (EPA 2002).
- ~2 million systems in NC; ~ 1 million systems in watersheds draining to coast (54% of residences) (mod. from Pradhan et al. 2007)

Nitrogen Treatment by Onsite Systems



OWTS –variable treatment of N (10-90%)
(Valiela et al. 1997, Oakley et al. 2011, Humphrey et al. 2010, D'Amato et al. 2016).

?

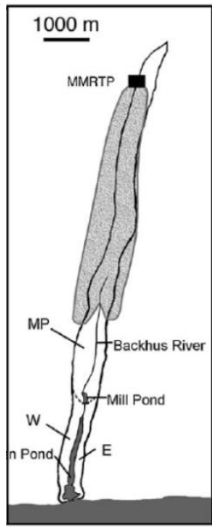
- N is present as DON, NH4+, and NO3-. Nitrate (NO3-) tends to be mobile in sandy soils and is readily transported.
- Wastewater can contain > 100 mg/l of N, drinking water standard is 10 mg/l NO3-N and blooms can occur at 1-2 mg/l.
- Because systems rely on the thickness of unsaturated soils (separation distance)- they are sensitive to water table depth and flooding

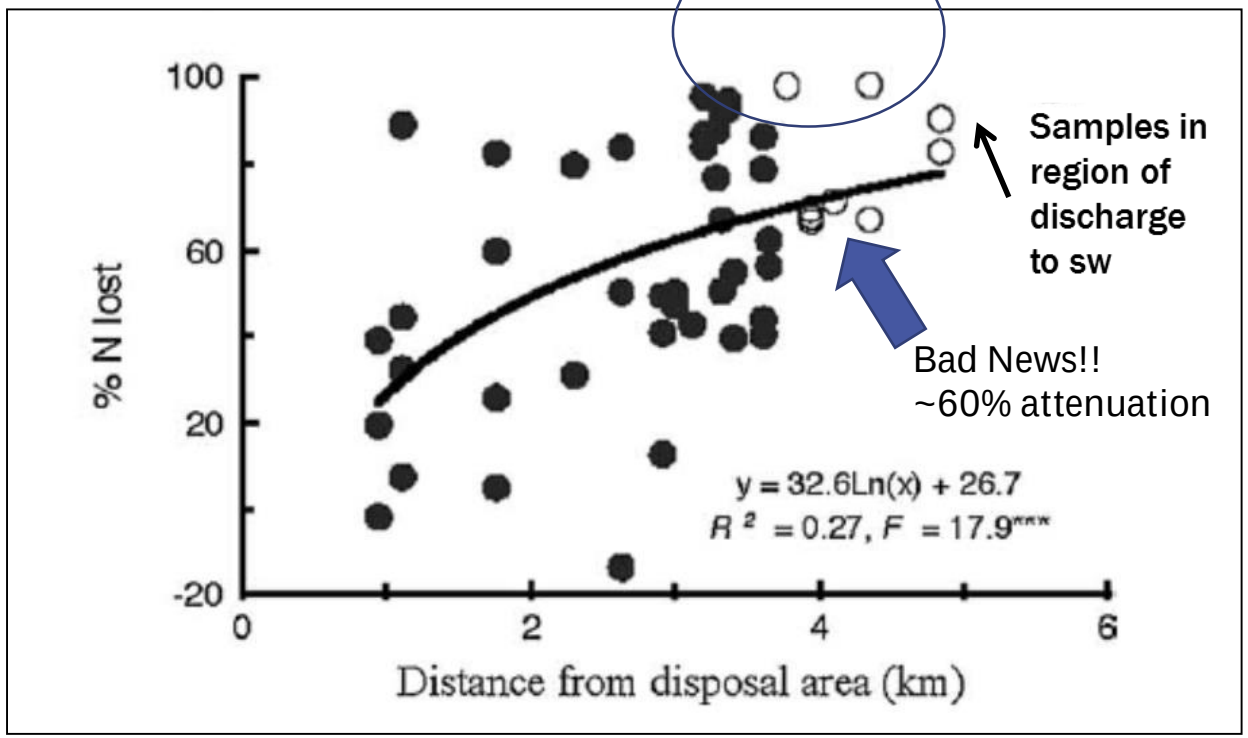
Nitrogen Attenuation (Retention/Loss) between Drainfield & Surface Water

Variable treatment of nitrogen (Valiela et al. 1997, Oakley et al. 2011) due to:

- Biological uptake
- Dilution/dispersion
- Denitrification
- Cation exchange

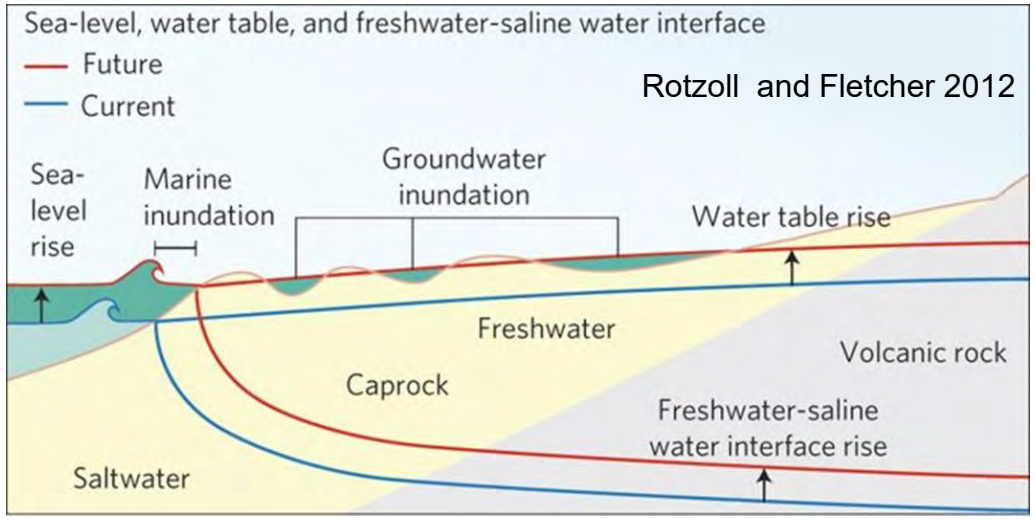
Good News!
> 90% attenuation

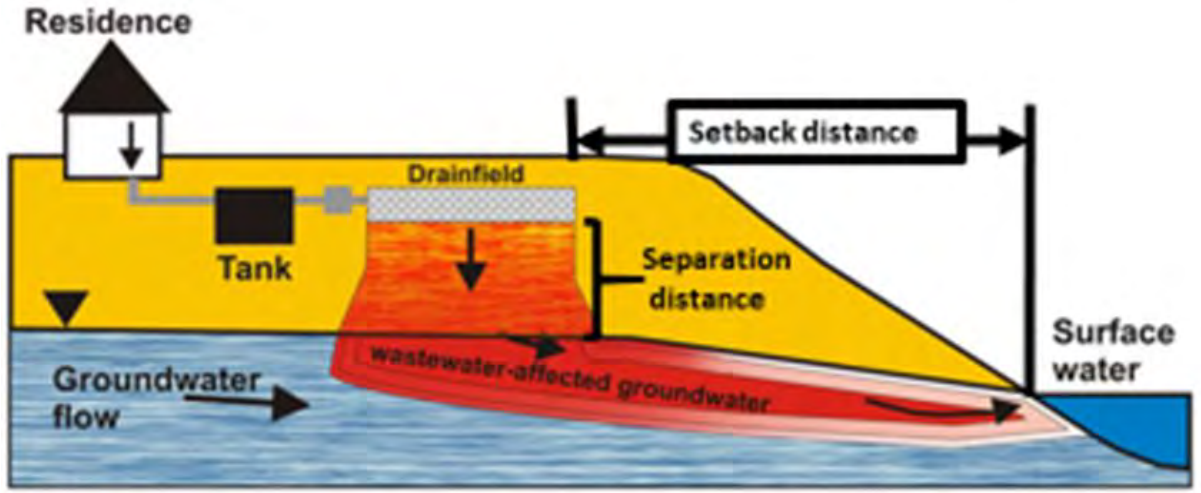




Modified from Kroeger et al. (2006). Massachusetts Military Reservation Treatment Plant, Cape Cod, MA

Sea Level Rise and Coastal Flooding: Reduces Separation and Setback Distances

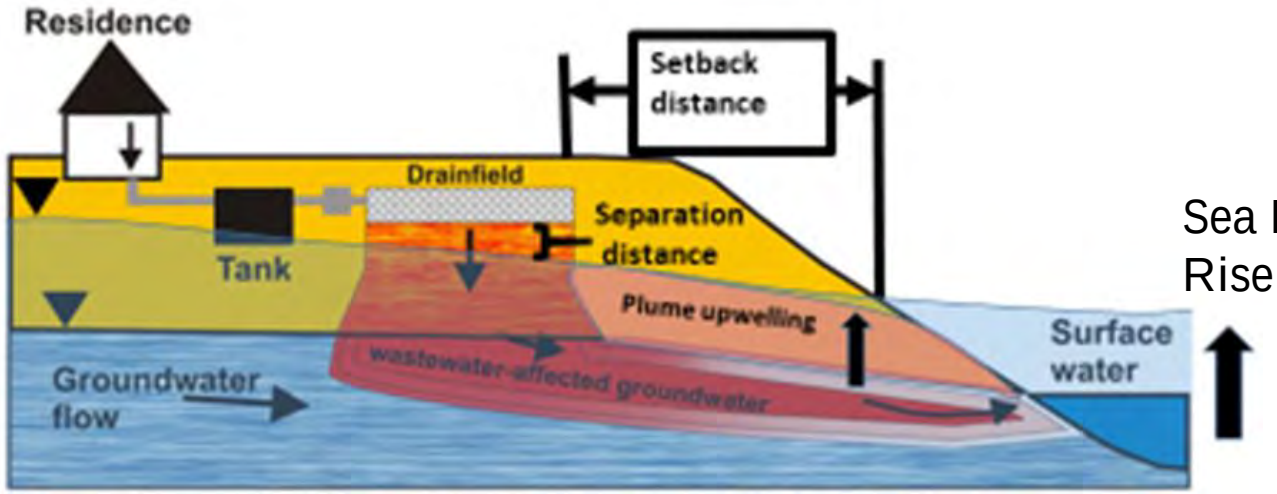




For Sandy Soils (Group 1) NC Requires:

45 cm (1.5 ft) separation distance between the water table and the drainlines

Drainfields to be setback at least 15 m (50 ft.) from surface waters (rules vary based on sw classification and size of system)

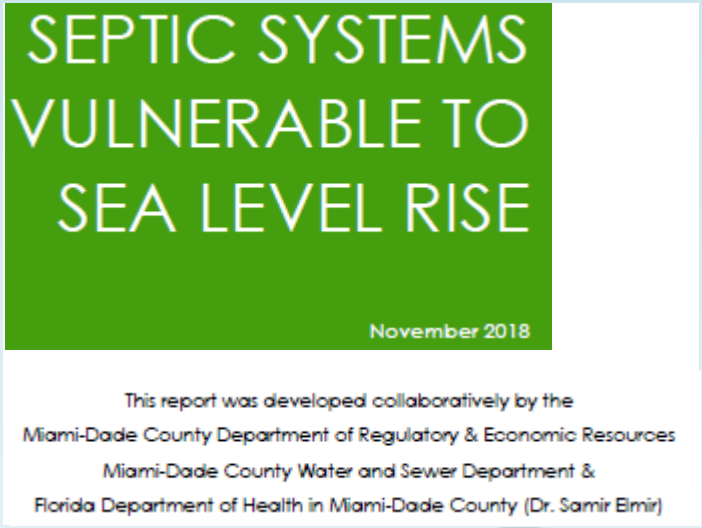


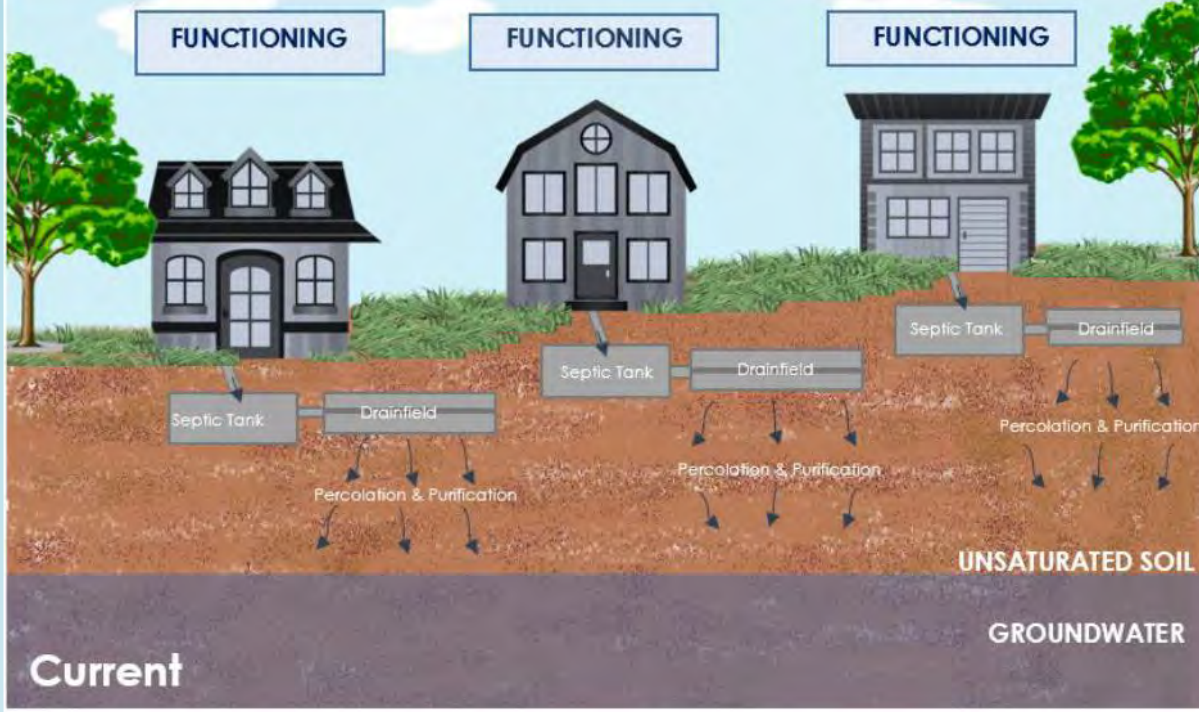
Sea Level Rise and Coastal Flooding: Can Compromise Onsite WW Treatment Systems

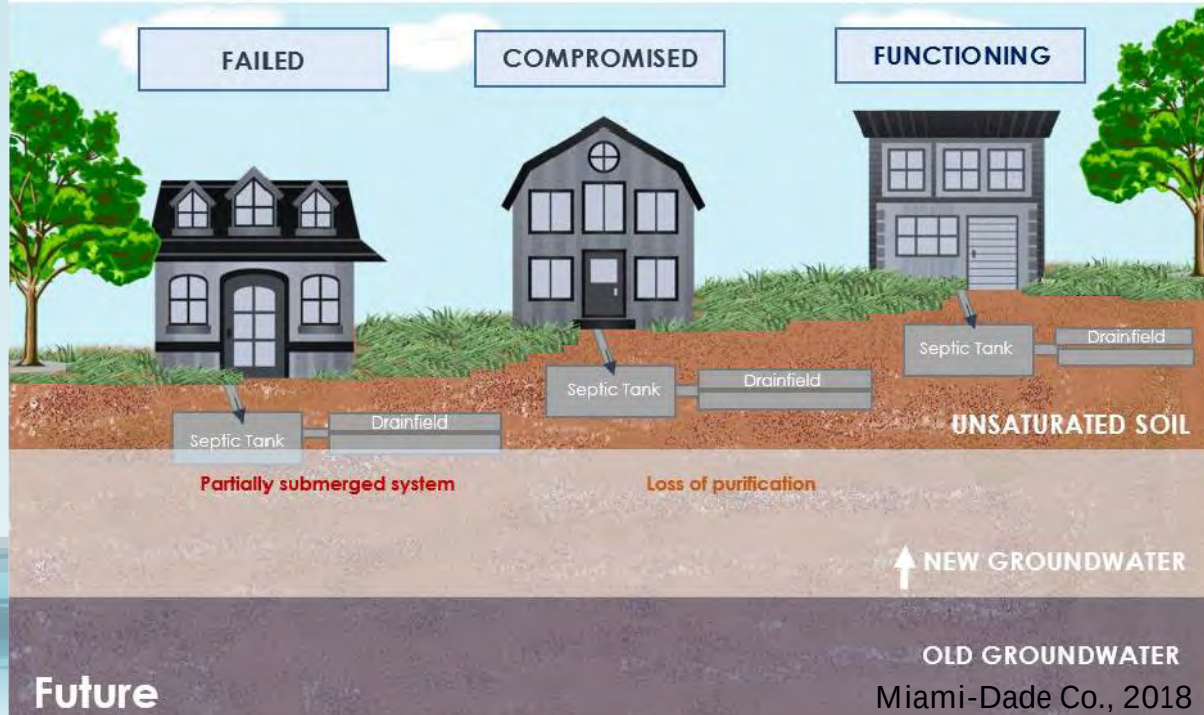
Previously functioning systems can:

1. Become compromised if separation distance declines

2. Fail if groundwater table rises into the drainfield





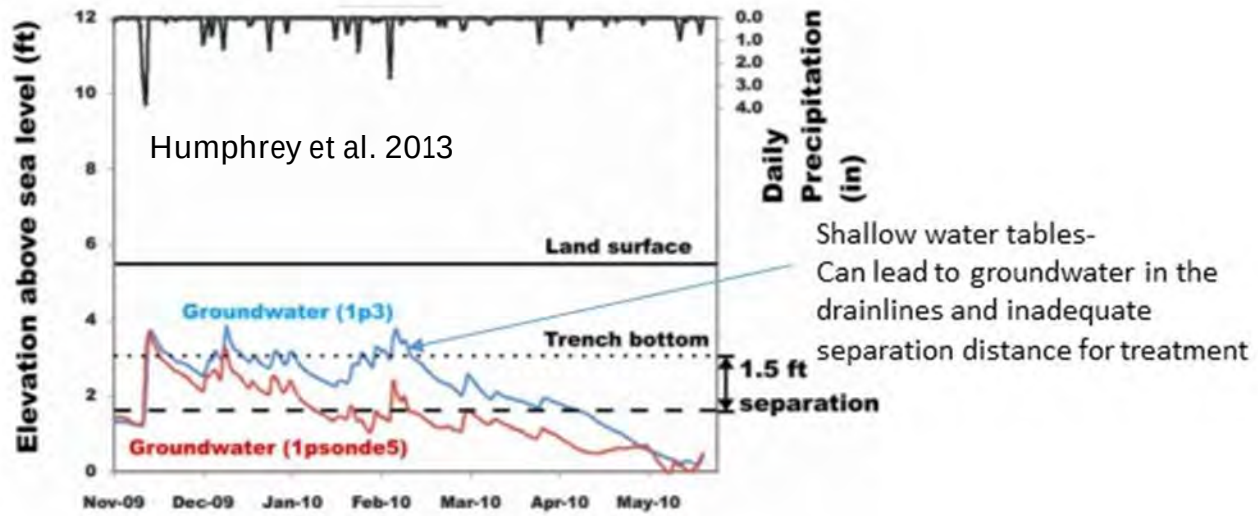


Miami-Dade Co., 2018

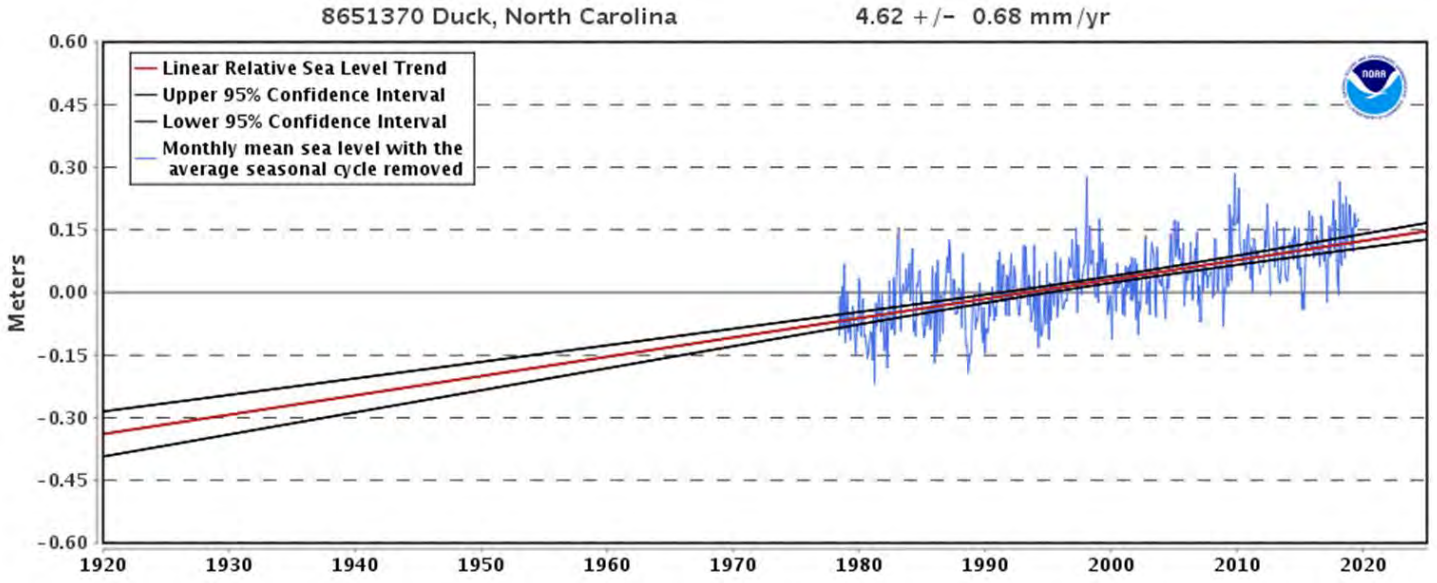
Unsaturated soils are needed to remove viruses and bacteria, treat nutrients, and other contaminants

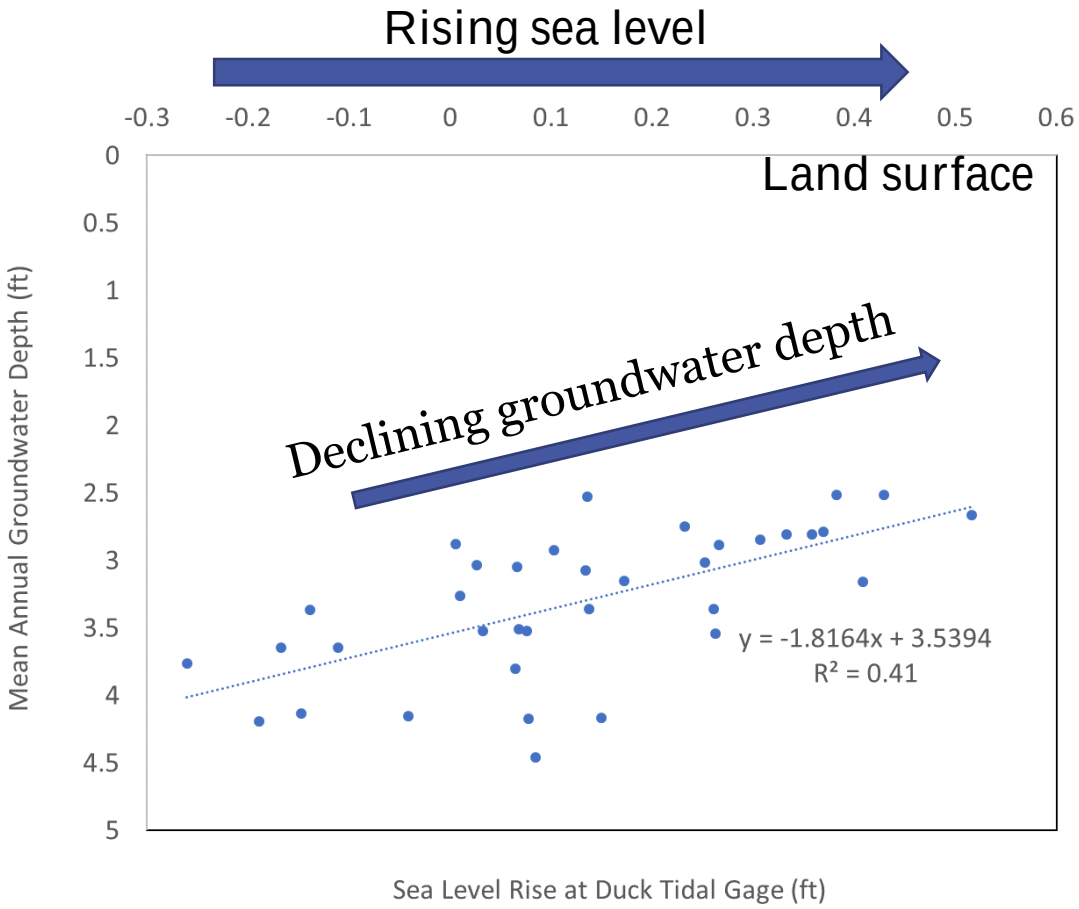
Residence in Washington NC that experienced storm surge flooding during Hurricane Irene (2011)

- During and after sunny-day or storm-related flood events, the septic drainfield can be flooded:
- the untreated waste can flow directly to the groundwater system
- wastewater may upwell to the land surface or back up into the residence
- wastewater can contaminate private drinking water wells
- the system will not function properly until the water table declines below the drainlines



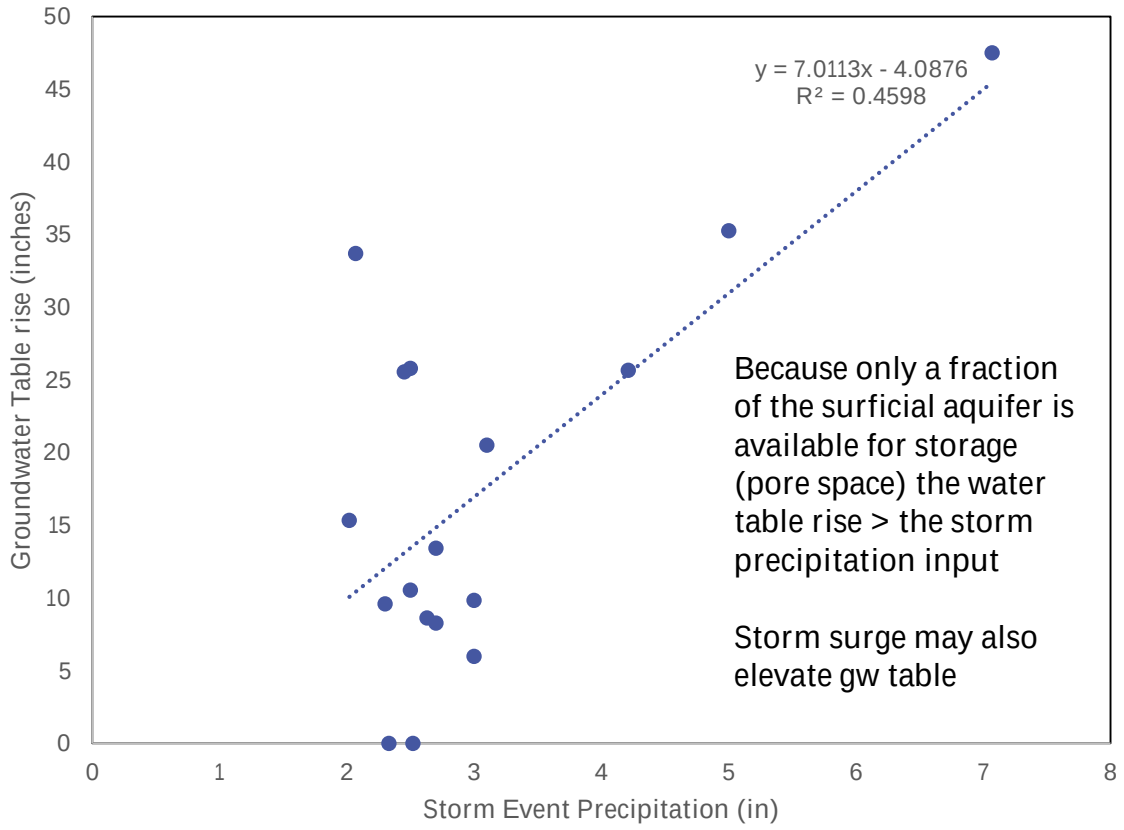
Sea Level Rise and Coastal Groundwater Levels: Example from Dare County

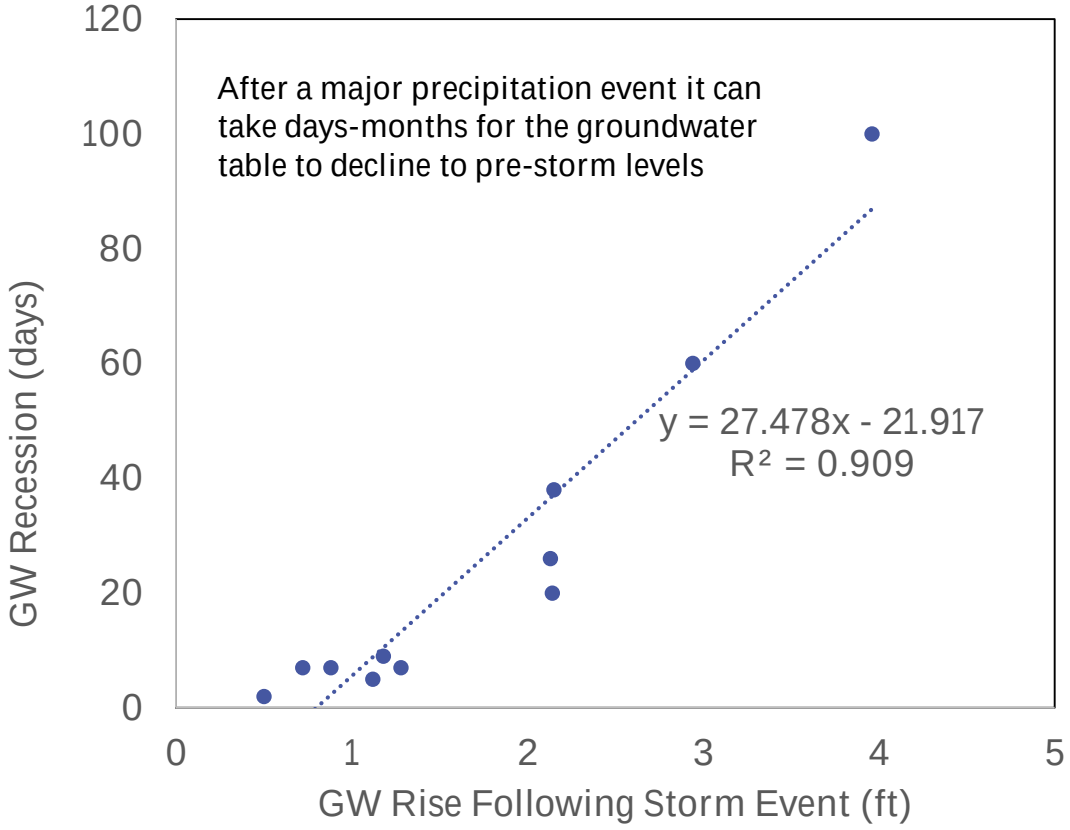




- DEQ GW Depth Data for 8 Wells in Dare Co. Surficial Aquifer
- Suggest a decline in water table depth since 1984 for 7/8 wells
- The rising water table corresponds with sea level rise

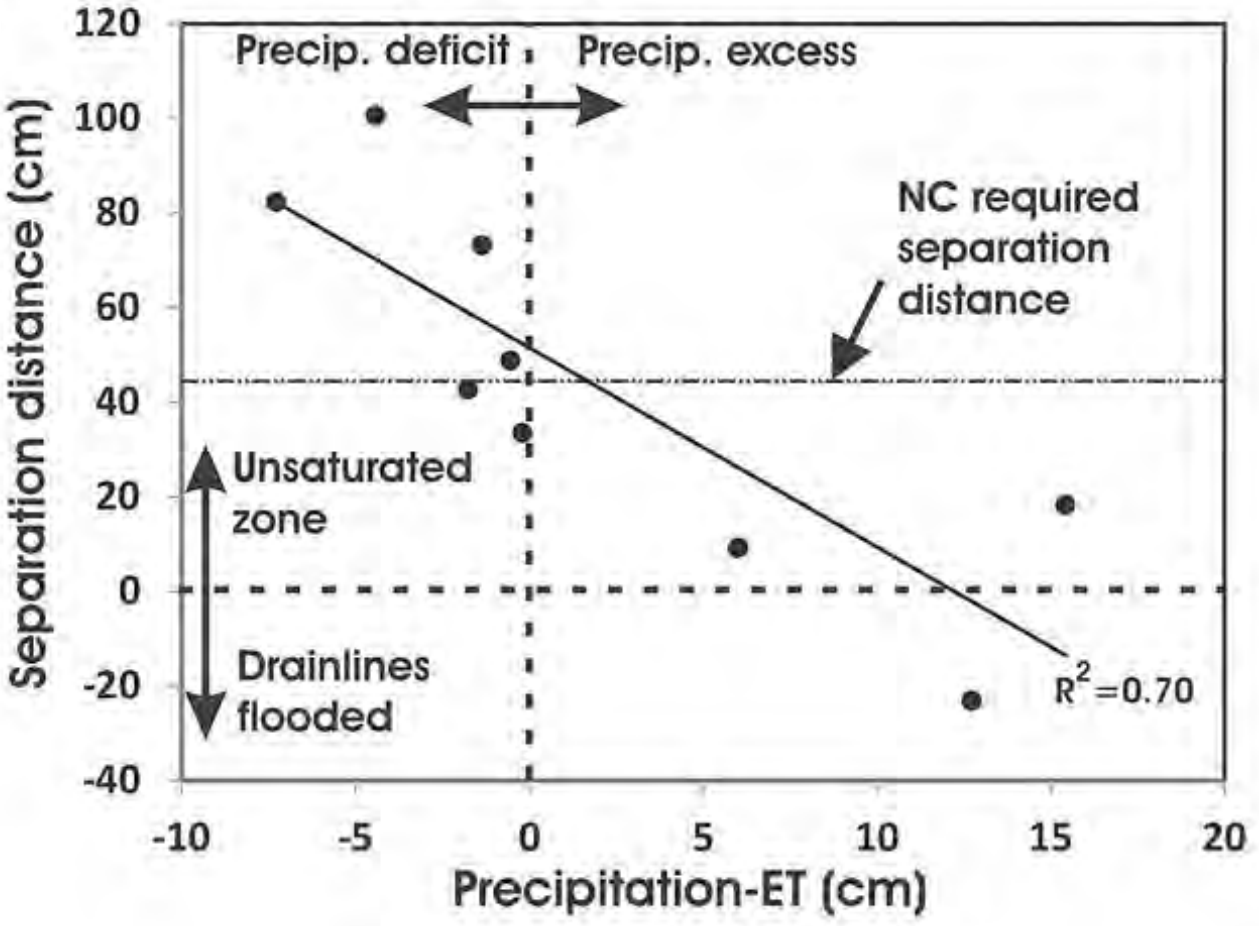
Extreme Precipitation Events – Effects on Coastal Groundwater Levels: Example from Wanchese Community Center GW Monitoring Well





Wanchese Community Center (DEQ monitoring well- 2012-2019 data- response to > 2 in rain events)

Sea Level Rise and Precipitation/Evapotranspiration – Effects on Septic System Separation Distance



Recent meteorological conditions influence the separation distance for coastal septic systems

Wet conditions- result in decreased separation and drainline flooding

Published November 10, 2014

Journal of Environmental Quality TECHNICAL REPORTS
GROUNDWATER QUALITY

Meteorological Influences on Nitrogen Dynamics of a Coastal Onsite Wastewater Treatment System

M. A. O'Driscoll,* C. P. Humphrey, Jr., N. E. Deal, D. L. Lindbo, and M. A. Zarate-Bermudez

Influence of Separation Distance on N treatment

Nitrogen removal can decline with declining separation distance (rising water table)!

PLOS ONE

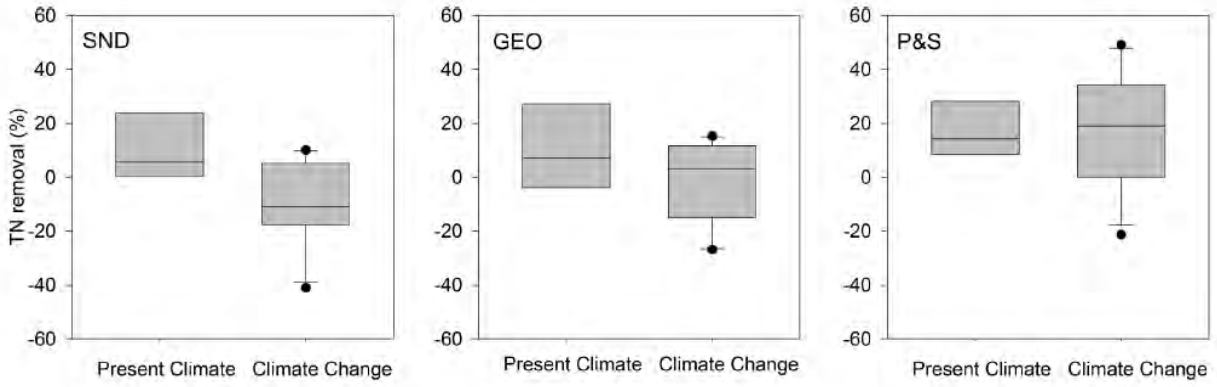
RESEARCH ARTICLE

Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change 2016

Jennifer A. Cooper[1¤]*, George W. Loomis[2], Jose A. Amador[1]

1 Laboratory of Soil Ecology and Microbiology, University of Rhode Island, Kingston, Rhode Island, United States of America, 2 New England Onsite Wastewater Training Center, University of Rhode Island, Kingston, Rhode Island, United States of America

¤ Current address: University of Florida Everglades Research and Education Center, Belle Glade, Florida, United States of America
* jencooper@ufl.edu



* Also see Karathanasis et al. 2006; Humphrey et al. 2011

RESEARCH PAPER

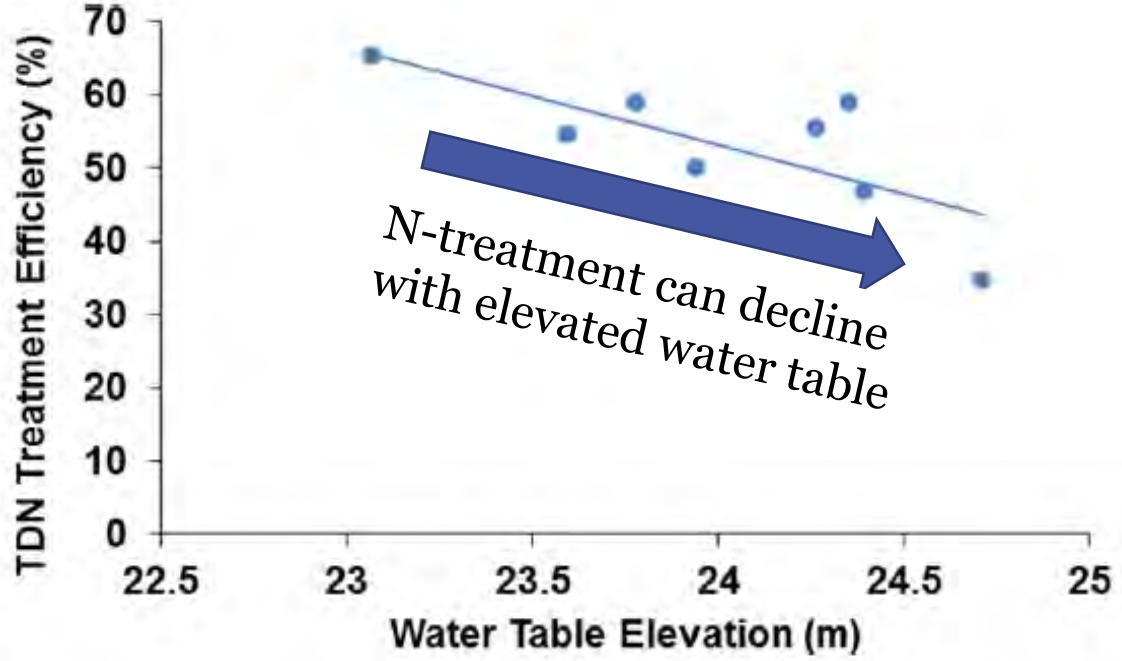
Water

CLEAN Soil Air Water 2017

www.clean-journal.com

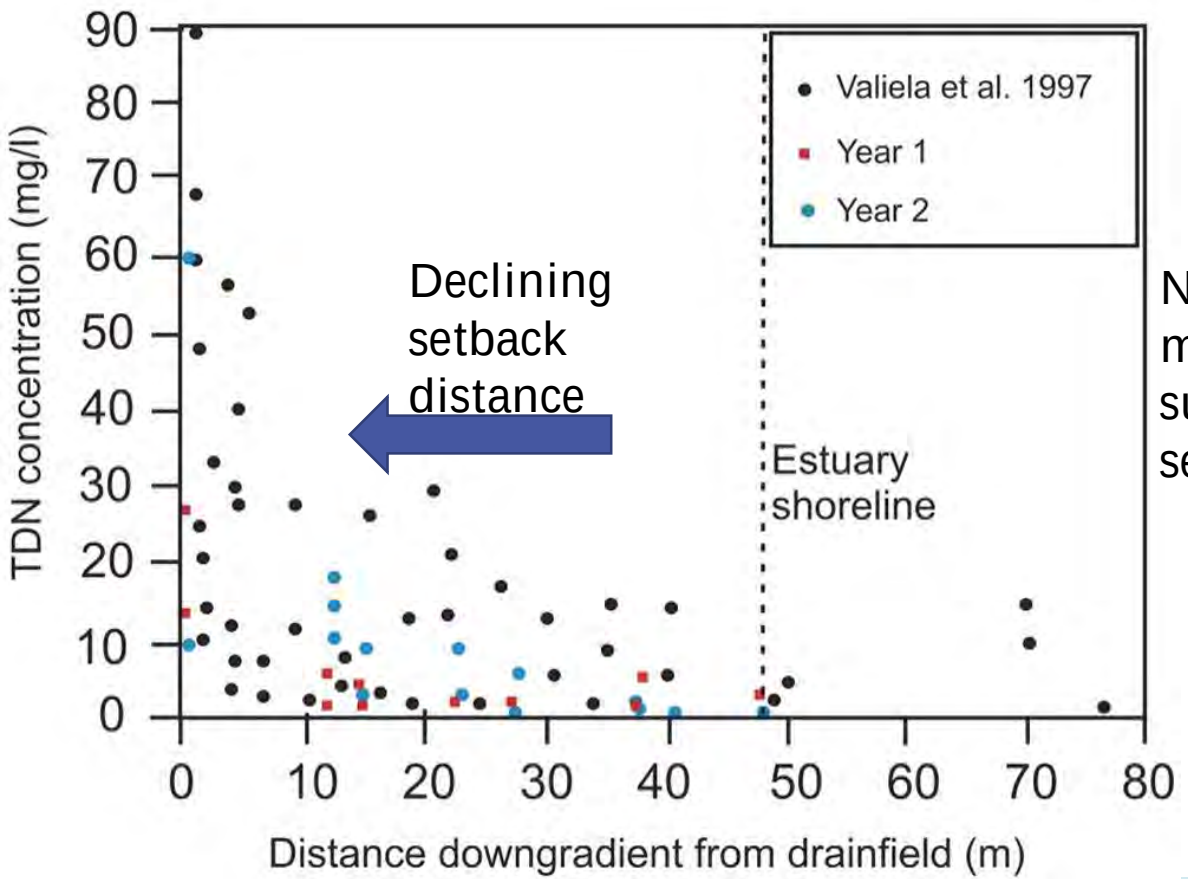
Nitrogen Treatment Efficiency of a Large Onsite Wastewater System in Relation to Water Table Dynamics

Charles P. Humphrey Jr., Guy Iverson, and Michael O'Driscoll*

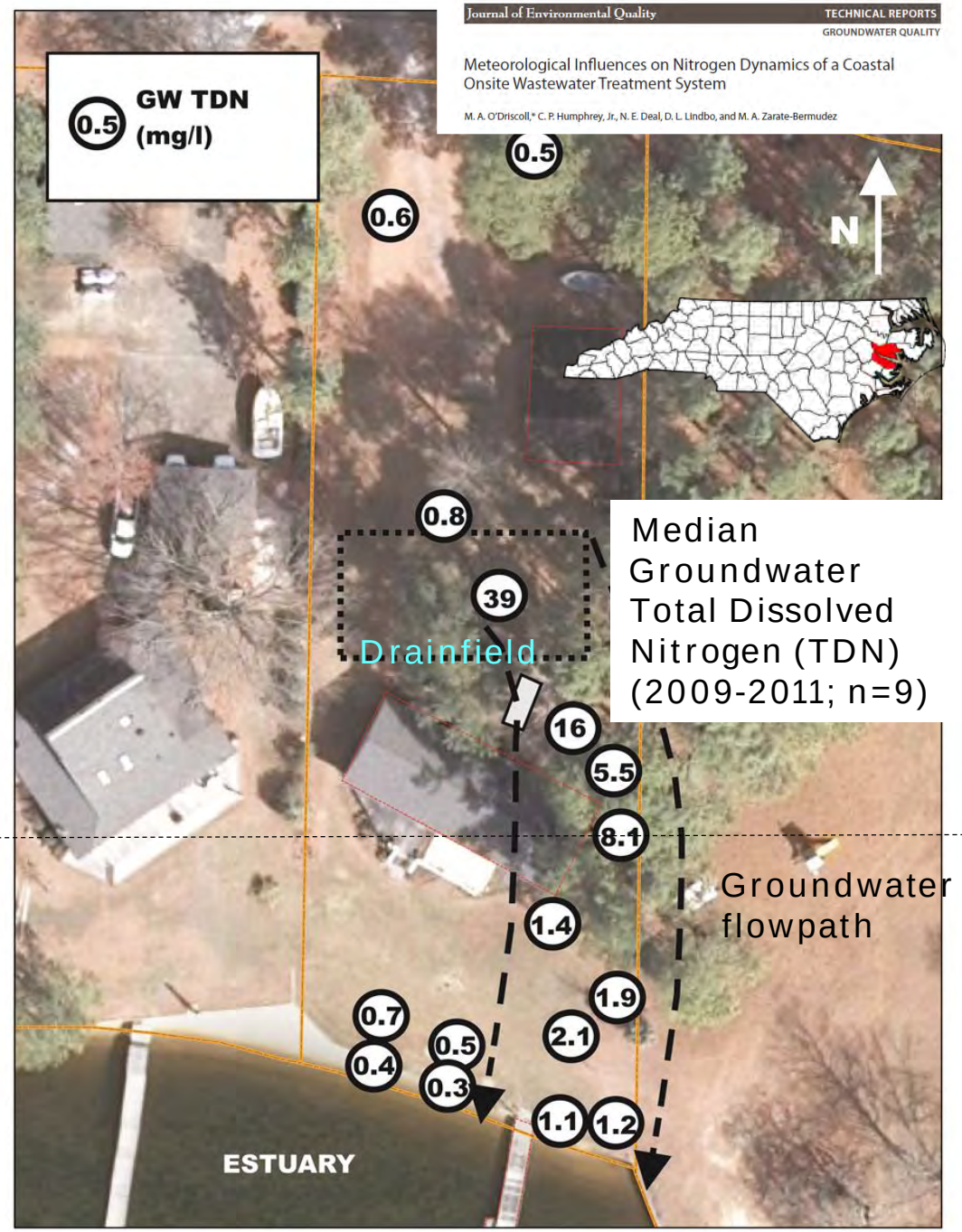


Nitrogen Treatment and Setback Distance

Shorter setbacks can result in less N attenuation & shorter subsurface residence times

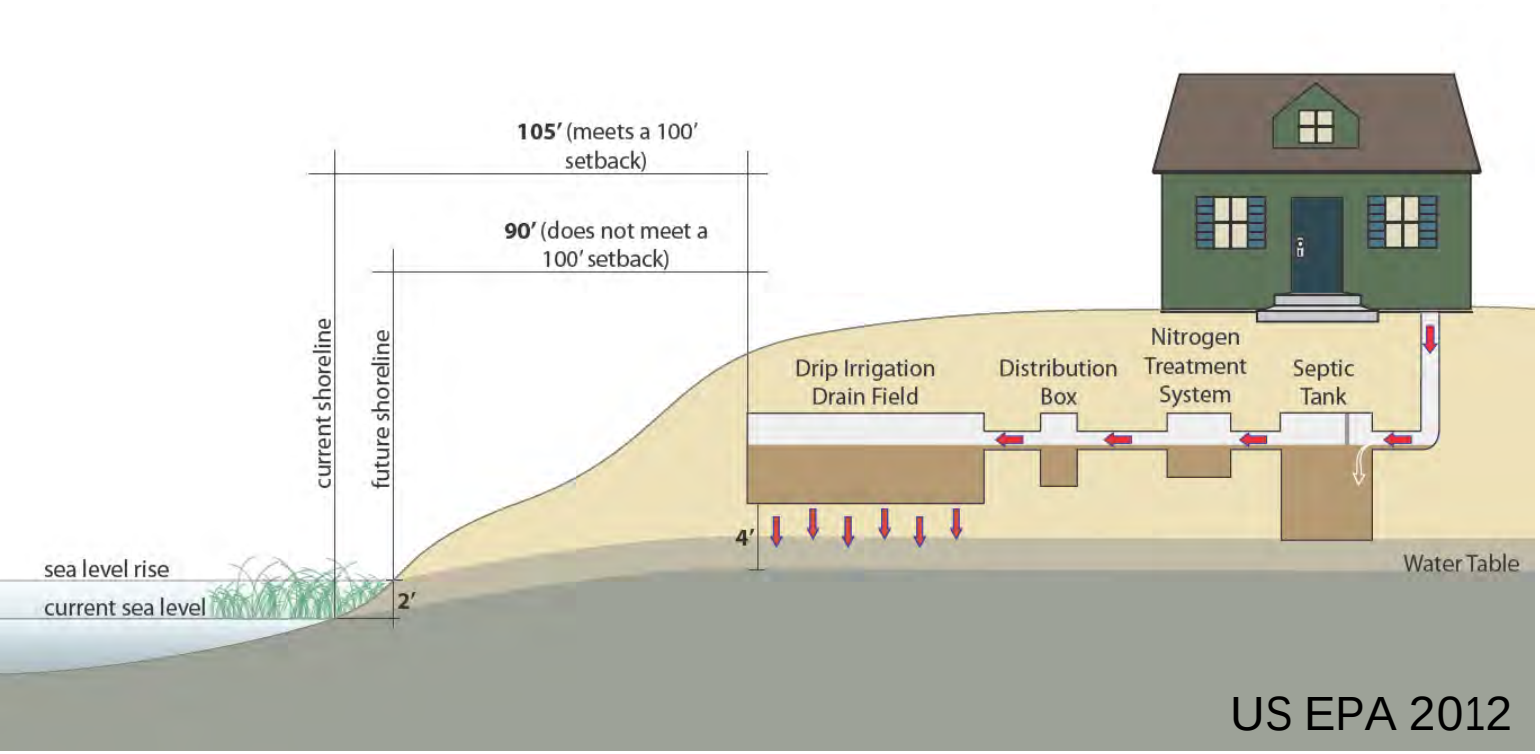


NC 15 m minimum surface water setback



Pamlico River Estuary, NC

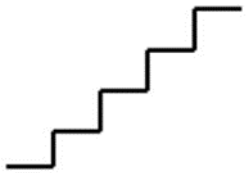
Sea level rise and coastal erosion:
Setbacks for coastal systems can decline at different rates



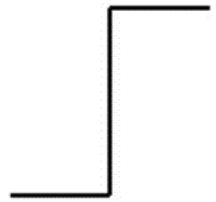
US EPA 2012

Lindbo, 2016

Incremental change



Step change



Effects of rising groundwater tables on onsite wastewater treatment

Not just a local problem.....

Rhode Island

Preliminary Evidence That Rising Groundwater Tables Threaten Coastal Septic Systems

Alissa H. Cox[1]; George W. Loomis[2]; and José A. Amador[3]

Abstract: Many communities along the southern Rhode Island coast rely on onsite wastewater treatment systems (OWTS), known as septic systems, to treat and disperse wastewater. System design requires sufficient vertical separation distance between the bottom of the drainfield and the seasonal high groundwater table to ensure an adequate volume of unsaturated soil to treat wastewater before it reaches the groundwater. Based on depth to groundwater table data submitted to the state regulatory agency as part of OWTS permit applications, groundwater tables along the southern Rhode Island coast have been rising at a rate of 14 mm/year since 1964. Communities where potable water is imported have greater rates of rising groundwater tables, up to 17 mm/year. From a mass balance perspective, precipitation, human wastewater inputs, and sea level rise represent the major factors elevating coastal groundwater tables, whereas evapotranspiration, discharge of groundwater to coastal waterbodies, and drinking water extraction are the major components lowering groundwater tables. As water inputs continue to change in the coming decades, rising groundwater tables may reduce OWTS functionality, threatening coastal drinking water aquifers and coastal ecosystems with nutrient and pathogen pollution. **DOI: 10.1061/JSWBAY.0000887.** © *2019 American Society of Civil Engineers.*

Author keywords: Wastewater; Onsite wastewater treatment; Septic system; Separation distance; Coastal resilience; Coastal groundwater; Rising groundwater table; Coastal communities; Coastal resilience planning; Historic data set.

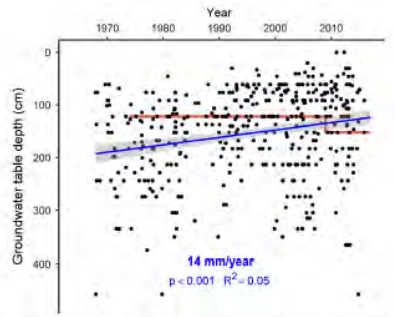


Fig. 2. Depth to groundwater measurements submitted to RIDEM as a part of the OWTS permitting process along the southern Rhode Island coast between 1964 and 2017 ($n = 427$). On the y-axis, 0 represents the ground surface. The red line indicates the minimum depth to water table in critical resource areas, as per RIDEM regulations, which changed in 2008. The blue line represents the linear regression (shaded grey region indicates the 95% confidence interval).

J. Sustainable Water Built Environ., 2019, 5(4): 04019007

Florida

SEPTIC SYSTEMS VULNERABLE TO SEA LEVEL RISE

November 2018

Final Report in support of Resolution No. R-911-16

This report was developed collaboratively by the
Miami-Dade County Department of Regulatory & Economic Resources
Miami-Dade County Water and Sewer Department &
Florida Department of Health in Miami-Dade County (Dr. Samir Elmir)

2018

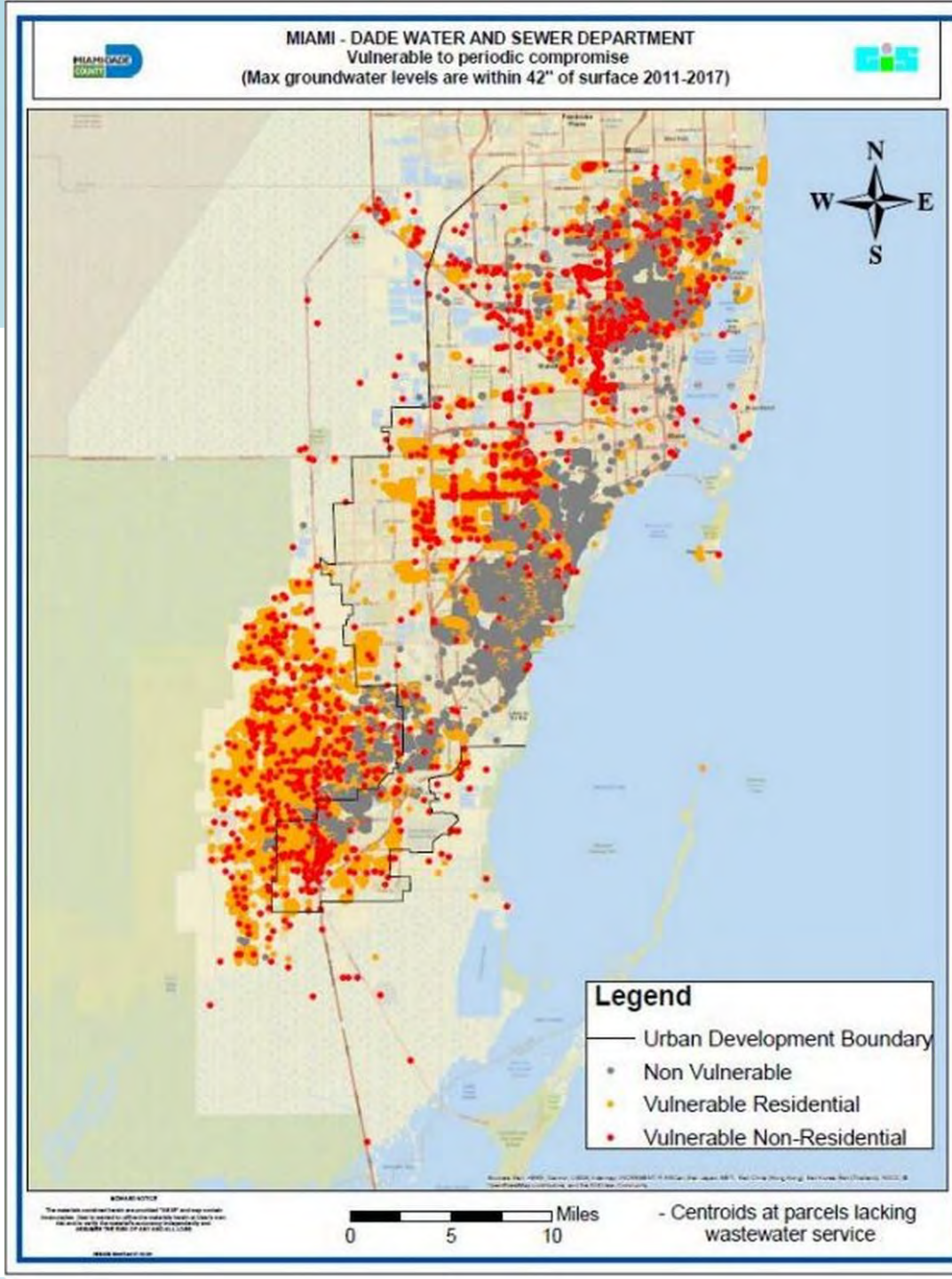
miamiherald.com/news/local/environment/article224132115.html

ENVIRONMENT

A $3 billion problem: Miami-Dade's septic tanks are already failing due to sea rise

BY ALEX HARRIS

A Miami-Dade neighborhood that relies on septic tanks experiences flooding during the 2016 King Tide. A new report commissioned by the county shows that half of the county's septic tanks break down yearly, a problem that sea level rise will worsen. *MIAMI-DADE COUNTY*



Summary

Sea Level is rising along North Carolina's Coast (and so is the water table).

Coastal storms and storm surge can cause elevated water tables.

Depth to water table, thickness of the unsaturated zone, and setback distance from surface waters are important variables that control the effectiveness of onsite wastewater treatment systems.

Future work should evaluate alternatives that can work effectively in shallow water table conditions.

Current and Future Work:
Wastewater Infrastructure Tipping Points:
Prioritizing Implementation of Climate Adaptation Plans in Decentralized Systems

Led by:
Jane Harrison
North Carolina Sea Grant

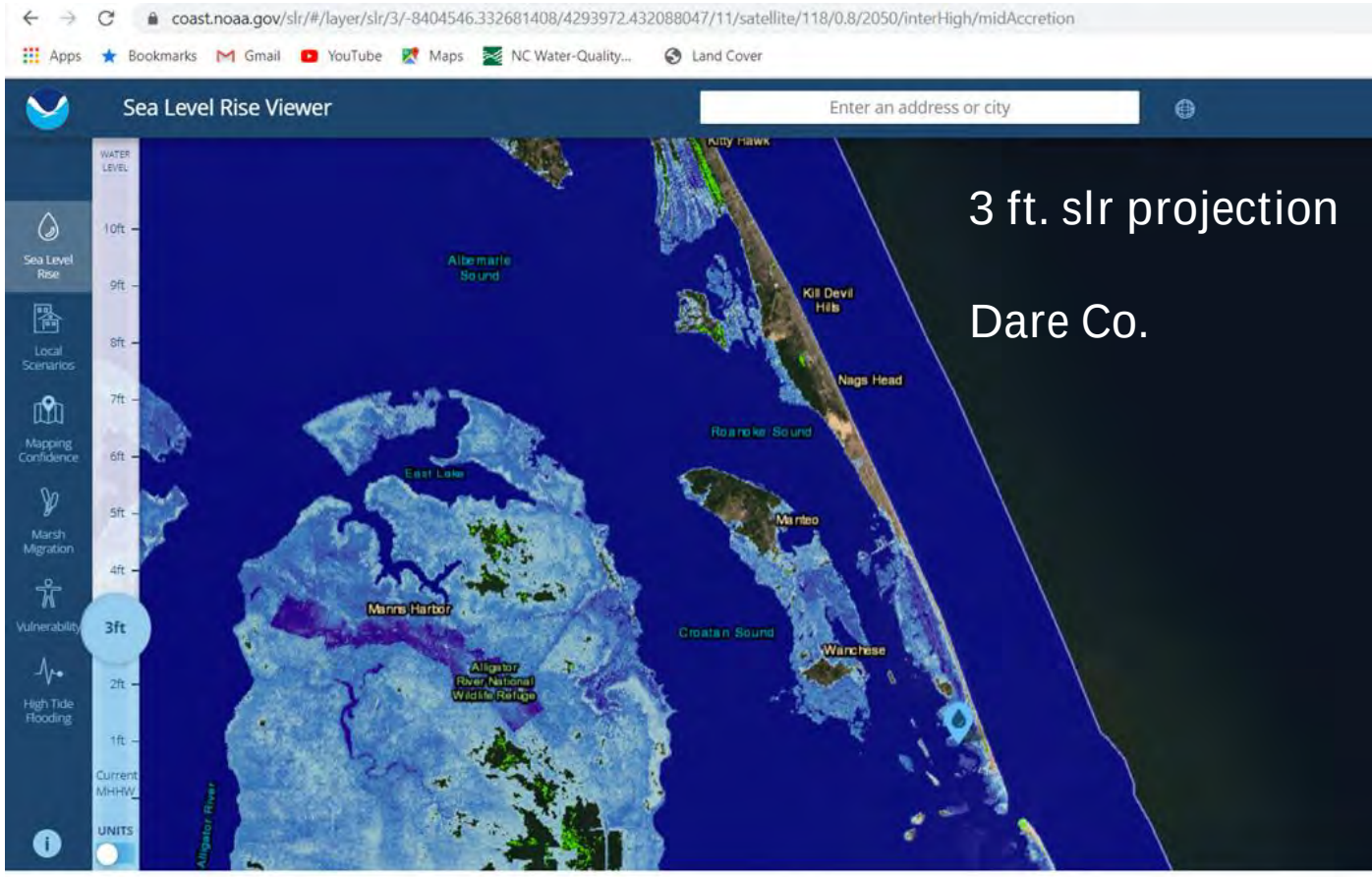
Eric Edwards & Jared Bowden
North Carolina State University

Charles Humphrey & Mike O'Driscoll
East Carolina University

Katie Hill
University of Georgia

Community Partners:
Nags Head, NC and Folly Beach, SC

Objective: evaluate onsite ww technologies under various climate conditions to help communities cost effectively and legally implement climate adaptation plans for ww infrastructure.



Thanks for your attention! Questions?

(Fortunately) less common wastewater hazards (for another talk!)


Thu, Nov 14, 2019

Newsweek

U.S. | World | Business | Tech & Science | Culture | Newsgeek | Sports | Health | Opinion

U.S.

FLORIDA COUPLE'S TOILET EXPLODES AS LIGHTNING STRIKES NEAR SEPTIC TANK: 'PROOF WHY YOU SHOULDN'T GO NEAR THE BATHROOM IN A THUNDERSTORM'

Acknowledgments

- Nick Mahoney, Guy Iverson, Eliot Anderson-Evans, Sean Thieme, Keaton Henry, Rob Howard, Jonathan Harris, Sarah Hardison, Adam Trevisan, Matt Smith (ECU)
- Charlie Humphrey (ECU), Eban Bean (U of Florida), Max Zarate (CDC), Dave Lindbo (NCSU), Nancy Deal and Steven Berkowitz (DHHS), Alex Manda (ECU), Sid Mitra (ECU), Dave Mallinson (ECU), Jane Harrison (NC Sea Grant), Lindsay Dubbs (UNC, CSI), Eric Edwards & Jared Bowden (NCSU), and Katie Hill (U GA)
- Jim Watson, John Woods, and Cait Skibiel (ECU)
- ECU Geological Sciences, Environ. Health, Coastal Studies, and Water Resources Center
- NC DEQ, CDC, and NOAA

And – Homeowners, Facilities Managers, and Plant Operators!