# The Effects of Sea Level Rise on RI's Salt Marshes

Held on Wednesday, April 16, 2014
Save The Bay, Providence, RI

The Eastern U.S. is a hotspot for sea level rise. Between 1950 and 2009, sea level rise rates between Boston and Cape Hatteras were three to four times higher than the global average, and in recent years, actual water levels have averaged more than 10 cm greater than predicted. There are reports of salt marsh deterioration and loss on Cape Cod, Long Island, and Chesapeake and Delaware Bays, and anecdotal evidence of marsh loss in Rhode Island. This workshop explored new information and research on the condition of our salt marshes and management strategies related to sea level rise in Rhode Island and surrounding states. A series of presentations by researchers and restoration practitioners from RI and surrounding states were followed by an afternoon session of break-out group discussions. Attendees came prepared to share their thoughts and suggestions on how to strengthen coordination and move forward with approaches to help increase the resilience of our coastal marshes.

**Target Audiences:** Researchers, natural resources managers, restoration practitioners, and conservation groups.
This workshop was sponsored by the Narragansett Bay Research Reserve, Save the Bay, EPA, and the RI CRMC. For more information, please contact Jennifer West at jennifer@nbnerr.org or 401-222-4700 x 7413.
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Agenda
Abstracts
Attendee List
Presentation Comments & Q&A
Break-out Group Notes (Management, Monitoring, Restoration)
NBNERR Sentinel Site (fact sheet)
The role of the metonic cycle in vegetation change and the eroded edge(poster)
Special Edition of the Narragansett Bay Journal: Salt Marshes & Sea Level Rise

## Presentations & Materials

A Salt Marsh Retrospective for the Future (Adamowicz)
Vulnerability of RI Salt Marshes to Accelerated Sea Level Rise (Watson)
Late Holocene and Anthropocene Sea Level Rise: Past, Present and Future for RI (Boothroyd)
The Declining Role of Organic Matter in Narragansett Bay Salt Marsh Accretion (Carey)
Dieback Events Accelerate Ongoing Spartina patens Loss in RI Salt Marshes(Raposa)
Developing a Salt Marsh Assessment Focused on the Impacts of Rapid Sea Level Rise (Cole Ekberg)
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Salt Marshes and Sea Levels in Eastern Long Island Sound (Warren)
Marsh Elevation Monitoring Efforts and Conservation Strategy Development by the Nature Conservancy on Long Island, NY (Starke)
Can Tidal Marsh Birds Persist in the Face of Climate Change? (Field)
Salt Marsh Adaptation Strategies in RI in Light of Sea Level Rise (Ferguson)
Sea Level Rise Impacts on Salt Marshes: Implications for Coastal Zone Management in RI (Chaffee)
Long Island Sound Study Wetland Loss Workshop Proceedings
Salt Marsh Trends in Selected Estuaries of Southwestern Connecticut (USFWS)
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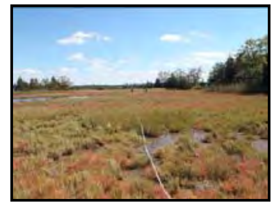
# The Effects of Sea Level Rise on RI's Salt Marshes



**Wednesday, April 16, 2014 | 9:00 a.m. - 3:30 p.m.**
**Save The Bay, Providence, RI**

## Objectives

- To share information pertaining to sea level rise effects on Rhode Island coastal marshes
- To discuss potential adaptation and management/restoration strategies
- To strengthen coordination between research and management/restoration sectors

## AGENDA

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| 8:30 am | ~~~~~~~~~~~~~~~~~~~~~~~~*Coffee & Sign-In*~~~~~~~~~~~~~~~~~~~~~~~~ |
| 9:00 am | **Welcome**<br>*Jonathan F. Stone, Executive Director, Save The Bay*<br>*Jennifer West, Coastal Training Program Coordinator, Narragansett Bay National Estuarine Research Reserve* |
| 9:15 am | **A Salt Marsh Retrospective for the Future**<br>*Susan C. Adamowicz, Ph.D., Coastal Biologist, U.S. Fish and Wildlife Service* |
| 9:45 am | **Vulnerability of Rhode Island Salt Marshes to Accelerated Sea Level Rise**<br>*Elizabeth B. Watson, Ph.D., Ecologist, U.S. Environmental Protection Agency* |
| 10:00 am | **Late Holocene and Anthropocene Sea Level Rise: Past, Present and Future for Rhode Island**<br>*Jon C. Boothroyd, Ph.D., Department of Geosciences, University of Rhode Island* |
| 10:15 am | **The Declining Role of Organic Matter in Narragansett Bay Salt Marsh Accretion**<br>*Joanna Carey, Ph.D., ORISE Postdoctoral Fellow, US Environmental Protection Agency* |
| 10:30 am | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~*Break*~~~~~~~~~~~~~~~~~~~~~~~~~~~~ |
| 10:45 am | **Dieback Events Accelerate Ongoing *Spartina patens* Loss in Rhode Island Salt Marshes**<br>*Kenneth Raposa, Ph.D., Research Coordinator, Narragansett Bay National Estuarine Research Reserve* |
| 11:00 am | **Developing a Salt Marsh Assessment Focused on the Impacts of Rapid Sea Level Rise**<br>*Marci Cole Ekberg, Ph.D., Coastal Ecologist, Save The Bay* |
| 11:15 am | **A GIS Assessment of Salt Marsh Change in Rhode Island from 1981 to 2008**<br>*Meghan Nightingale, Wild & Scenic* |

11:30 am **Salt Marshes and Sea Levels in Eastern Long Island Sound**
*R Scott Warren, Ph.D., Tempel Professor of Botany, Emeritus, Connecticut College*

11:45 am *~~~~~~~~~~~~~~~~~~~~~~~~~~~~Lunch~~~~~~~~~~~~~~~~~~~~~~~~~~~~*

12:30 pm **Marsh Elevation Monitoring Efforts and Conservation Strategy Development by the Nature Conservancy on Long Island, NY**
*Adam Starke, Coastal and Marine Conservation Coordinator, The Nature Conservancy on Long Island*

12:45 pm **A Massachusetts Perspective on Climate Change Impacts to Wetlands**
*Marc Carullo, Coastal GIS and Habitat Specialist, MA Office of Coastal Zone Management*

1:00 pm **Can Tidal Marsh Birds Persist in the Face of Climate Change?**
*Chris Field, Ph.D. Candidate, University of Connecticut*

1:15 pm **Salt Marsh Adaptation Strategies in Rhode Island in Light of Sea Level Rise**
*Wenley Ferguson, Director of Habitat Restoration, Save The Bay*

1:30 pm **Sea Level Rise Impacts on Salt Marshes: Implications for Coastal Zone Management in RI**
*Caitlin Chaffee, Policy Analyst, RI Coastal Resources Management Council*

1:45 pm **Break-out group discussions**

**Purple:** What management questions related to salt marshes and sea level rise can researchers help address? *(facilitator: Walter Berry; notetaker: Jacob Peterson)*
**Orange:** What salt marsh monitoring strategies should be prioritized? *(facilitator: Bob Stankelis; notetaker: Brittany Foley)*
**Green:** How do we prioritize restoration opportunities (both existing strategies and new approaches) considering time and funding limitations? *(facilitator: Caitlin Chaffee; notetaker: Katherine Harrigan)*

2:35 pm **Group report-outs and discussion**

3:15 pm **Wrap-up and evaluations**

3:30 pm **Social hour**

# Abstracts

**A Salt Marsh Retrospective for the Future**
Susan C. Adamowicz, Ph.D., Coastal Biologist, U.S. Fish and Wildlife Service, Rachel Carson NWR, Wells, ME; susan_adamowicz@fws.gov

Salt marshes have been the subject of alteration since Colonial settlement in the early 1600s. For the past 4 centuries, salt marshes have been diked, drained, filled, impounded, invaded and now, seemingly set on a path to a warm drowning. Just as dramatic, however, has been the change in thought process and understanding of the ecological and ecosystem underpinnings that create and sustain salt marshes along our coasts. This presentation reviews, in a fast paced and somewhat arbitrary fashion, the history of salt marsh alterations in New England as well as various developments in ecological thought…*because we see what we know*. In order to successfully navigate the uncharted future of climate change, we must be able to simultaneously conserve and challenge our accumulated wisdom. The presentation closes by highlighting speakers and topics coming later in the day.

**Vulnerability of Rhode Island Salt Marshes to Accelerated Sea Level Rise**
Elizabeth B. Watson, Ph.D., Ecologist, U.S. Environmental Protection Agency, Narragansett, RI; Watson.Elizabeth@epa.gov

In the Northeastern U.S., salt marsh area is in decline. Habitat change analysis has revealed fragmentation, displacement of high marsh by low marsh species, and marsh drowning, while development of adjacent uplands limits upslope migration. Examination of historic air photos revealed significant loss in salt marsh vegetation between the 1970s and the present in Rhode Island, through tidal channel widening, shoreline erosion, and the development of interior ponded areas. Analysis of marsh loss patterns, water levels, and elevation at five RI sites (Brushneck Cove, Warwick, Mary Donovan Marsh, Little Compton, Nag Marsh, Prudence Island, Hundred Acre Cove, Barrington, Pettaquamscutt Cove, Narragansett) show that marsh loss patterns are strongly controlled by marsh elevation relative to mean high water (MHW), with marshes that are higher in elevation having less marsh loss than marshes that are situated below MHW. Using inundation experiments and additional elevation datasets, an elevation-productivity relationship was developed for *Spartina alterniflora* specific to the U.S. Northeast states of New York, Connecticut, Rhode Island, southern Massachusetts and current salt marsh orthometric heights were located on this curve. Nearly all of Rhode Island's salt marshes and 89% of salt marshes in these Northeastern states are located at elevations where growth is limited by inundation. These results are suggestive of strong links between current salt marsh loss patterns and accelerated sea level rise.

**Late Holocene and Anthropocene Sea Level Rise: Past, Present and Future for Rhode Island**
Jon C. Boothroyd, Ph.D., Department of Geosciences, University of Rhode Island; jon_boothroyd@uri.edu

World sea level rose from a low of -120 m below present levels 26,000 years ago (yBP) when the last continental ice sheets began to melt. Sea-level rise rose in a complex manner, slow at first, then more rapidly as the climate warmed. Much continental ice was gone by 5-7,000 yBP, consequently the rate of sea-level rise very rapidly slowed from meters per 100 years to a few centimeters. Studies in North Carolina marshes (Kemp and others, 2011) reveal that sea level remained more or less constant from 2000 yBP to about 150 yBP (1850 AD) when greenhouse gas emissions from the industrial revolution are interpreted to have begun induced anthropogenic climate change. Tide gauge records from NOAA tide stations in the northeast indicate about 25-30 cm of sea-level rise per century since 1900 AD. Recent satellite measurements of global sea-level rise indicate rises at rates of 32 cm per century and since 1993.

Accelerated sea-level rise estimates, rates based on presently measured greenhouse gas emissions since 1958, and future projected scenarios, plus projected temperature increases due to those emissions, give a number of ranges to 2100 AD. Projections range from a low of 27 cm (IPCC, 2013) to a high of 2.06 m

(NOAA, 2013). The RI CRMC (Coastal Resources Management Council) suggests planning for 1-1.5 m by 2100 (Sec 145, CRMC, 2014).

Geologic opinions vary as to whether sedimentation on present marsh surfaces in the northeastern US are keeping up with present sea-level rise and if not, why not. However, if the higher accelerated sea-level rise projections prove accurate, salt marshes will need to migrate (transgress) present upland environments. Also, an often overlooked geologic process and resulting product are the sedimentation of washover fans on barriers and on as surge platforms in coastal lagoons. These depositional features are the platform on which many present marshes exist in Rhode Island. They will be an important source of new substrate for future marsh migration and growth, if we leave them in place as they develop during major storm events.

**The Declining Role of Organic Matter in Narragansett Bay Salt Marsh Accretion**

Joanna Carey, Ph.D., ORISE Postdoctoral Fellow, U.S. Environmental Protection Agency, Narragansett, RI; joanna.carey@gmail.com

The Northeast US is experiencing some of the most severe impacts of climate change, including increased winter temperatures and accelerated relative sea level rise (RSLR). The sediment-poor, organic-rich nature of many Southern New England salt marshes makes them particularly vulnerable to these changes. In Narragansett Bay, RI the rate of RSLR has significantly ($p=0.02$) increased by almost 60% during the past 30 years, from 0.26±0.02 cm yr-1 (1931-1983) to 0.41±0.07 cm yr-1(1984-2011). Using radionuclide tracers (210Pb and 137Cs), we returned to Narragansett Bay, RI where salt marsh vertical accretion rates were documented 30 years ago in order to determine how marsh accretion has changed in recent years. Our results demonstrate a declining role of organic matter in contributing to vertical accretion across all study sites, which we attribute to higher decomposition rates fueled by higher temperatures. Further, at the marshes located more internal to the estuary, inorganic matter also contributes less to accretion, likely due to diminishing sediment supplies in the region. With organic and inorganic solids accounting for less of the accretion, several of the marshes appear to be experiencing symptoms of waterlogging, with water and porespace contributing to maintaining marsh elevation compared to historical values. Accretion rates (0.27-0.45 cm yr-1) at these waterlogged, organic-rich marshes (>40% sediment organic matter) are predominantly lower than the current (30-yr) rate of RSLR (0.41 ±0.07 cm yr-1). The diminishing role of both inorganic and organic matter in contributing to marsh accretion highlight a fundamental shift in how these marshes are maintaining their elevation in response to rising sea levels.

**Dieback Events Accelerate Ongoing *Spartina patens* Loss in Rhode Island Salt Marshes**

Kenneth Raposa, Ph.D., Research Coordinator, Narragansett Bay National Estuarine Research Reserve, Prudence Island, RI; kenny@nbnerr.org

New England salt marshes are currently impacted by multiple stressors, including accelerating sea level rise and recent anomalous high tides, which threaten marsh sustainability. If marshes are unable to keep pace with rising sea levels, impacts will include creek sloughing, ponding and vegetation dieback in the high marsh, and drowning. The National Estuarine Research Reserve's Sentinel Sites program is documenting salt marsh responses to sea level rise at two marshes in Narragansett Bay, RI. Long-term vegetation monitoring at these salt marshes shows that the salt meadow foundation species *Spartina patens* is decreasing significantly over time as it is largely replaced by *Spartina alterniflora*. If the current trend continues, *S. patens* may be lost from one marsh as early as 2017. Areas where *S. patens* declined were on average 4 cm lower in elevation than areas where *S. patens* remained stable. Vegetation dieback, which was related to unusually high tide levels, accelerated the loss of *S. patens* by 63%. *Spartina patens* high marsh will likely be lost from both marshes long before they begin to transgress into adjacent upland habitats. With sea levels expected to rise even faster, we predict that RI marshes will continue to lose salt meadow habitat and convert to stunted *S. alterniflora* interspersed with dieback. Our monitoring data indicate that managers need to consider adaptation efforts aimed at helping salt marshes keep pace with accelerating sea level rise.

**Developing a Salt Marsh Assessment Focused on the Impacts of Rapid Sea Level Rise**
Marci Cole Ekberg, Coastal Ecologist, Save The Bay, Providence, RI; mcole@savebay.org

In recent years, Save The Bay and Narragansett Bay Research Reserve staff have observed that many southern New England salt marshes seem to be showing initial signs of marsh response to the effects of rapid sea level rise and increased inundation due to anomalous tides. However, most of these observations of marsh degradation were anecdotal and not supported by quantitative field data. To address this, we developed and conducted a somewhat rapid assessment of Rhode Island's salt marshes during 2012 and 2013. Our goals were: 1) to assess the extent of die-off in the high marsh in response to factors such as increased sea level rise, higher tides, and heat/drought, and 2) to identify any restoration or adaptation opportunities. This presentation will discuss development, implementation and initial results of the assessment. We will highlight the collaboration with scientists from the Narragansett Bay National Estuarine Research Reserve, US Fish and Wildlife Service, and the Environmental Protection Agency on the protocol development and implementation.

**A GIS Assessment of Salt Marsh Change in Rhode Island from 1981 to 2008**
Meghan Nightingale, Wild & Scenic, Richmond, RI; Meg.gallagher@pobox.com

Salt marsh habitat is under pressure from development on the landward side, and sea level rise from the seaward side. A 25-year assessment of the population status of the Seaside Sparrow prompted further analyses to evaluate habitat changes to help us better understand the 40% average decrease in the sparrow's populations. To assess landscape changes over the study period we used available spatial data for 11 salt marsh sites to quantify 1) the increase in residential and commercial development within 150 m and 1 km buffers surrounding each marsh, and 2) the loss of salt marsh habitat at each site. Over the course of the study, development within the 150 m buffer increased by an average of 69%, and salt marsh habitat decreased by an average of 14%. It has been shown that loss of salt marsh habitat is significantly correlated with urban growth, although our findings did not show a strong relationship between the increased development within the buffers and salt marsh loss. However, one consequence of increased adjacent residential land use can be elevated levels of nitrogen input to the watershed, which changes the plant mosaic of the marsh. These changes can include increased areas of *Phragmites australis*, which were documented in the historical and current delineations of the salt marsh during this study.

**Salt Marshes and Sea Levels in Eastern Long Island Sound**
R Scott Warren, Ph.D., Tempel Professor of Botany, Emeritus, Connecticut College, New London, CT; rswar@conncoll.edu

The long-term 1939-2013 rate of RSLR (Relative Sea-Level Rise) at the New London tide gauge is 2.6 mm $yr^{-1}$, near the maximum rate of marsh accretion reported in eastern LIS salt marshes. RSLR since the late 1980s, however, is 4.5 mm $yr^{-1}$, more than double the rate over the first 40 years of the New London record. This increase in RSLR is consistent with recent literature and the current rate is *ca*. 1.5x the highest recorded rate of marsh accretion. A decade of SET measurements at the Barn Island system on Little Narragansett Bay and an accretion pin array at the Mamacoke Marsh on the Thames River confirm earlier work demonstrating that marsh surface elevations these systems are not keeping up with RSLR and that marsh hydroperiods are increasing. Observed vegetation changes on these and other area salt marshes are consistent with increasing hydroperiod, particularly in areas that started with lower "elevation capital". Locations with appropriate topography and no anthropogenic barriers demonstrate another aspect of RSLR: replacement of upland vegetation with "upper border", brackish marsh plant species as well as typical upper border salt marsh invertebrates.

**Marsh Elevation Monitoring Efforts and Conservation Strategy Development by the Nature Conservancy on Long Island, NY**
Adam Starke, Coastal and Marine Conservation Coordinator, The Nature Conservancy on Long Island; astarke@tnc.org

The Nature Conservancy on Long Island began monitoring coastal salt marshes in 2008 in large part to inform local conservation strategies in the area. Since that time, our efforts have expanded both in scope and scale and although the question has remained the same; "How do we preserve, protect, and restore our salt marshes?" our thinking on the issue has evolved. TNC now has nine active SET-MH monitoring sites across LI, which join a growing number of stations maintained by partners, all in pursuit of identifying the current status and the ultimate fate of our salt marshes. By collaborating with research partners from the EPA and academia we hope to begin parsing out overall marsh elevation changes due to surface and subsurface marsh processes. Our goal in these efforts is to identify key threats which may be addressed to encourage resilient, healthy marsh systems. As we began moving our focus from local-scale conservation strategies to regional and global-scale, we recognized the importance of unifying the efforts made across the region. This led to a recent proposal to formalize a group of marsh elevation practitioners in the Northeast to encourage collaboration across the region.

**A Massachusetts Perspective on Climate Change Impacts to Wetlands**
Marc Carullo, Coastal GIS and Habitat Specialist, MA Office of Coastal Zone Management, Boston, MA; marc.carullo@state.ma.us

The Massachusetts Office of Coastal Zone Management has a long-standing program to help communities and homeowners with coastal erosion, flooding, storm damage, sea level rise, and other climate change impacts. StormSmart Coasts is a nationally-recognized program with a large network of policy-makers, practitioners, and concerned citizens with a track record for real change. CZM/StormSmart Coasts has been promoting the use of green infrastructure, or "soft" techniques, to increase coastal resilience to sea level rise and storm surge for some time. Until recently, salt marshes and other wetland resources have often been overshadowed in discussions with the coastal community at-large, with the focus on near-term impacts to community infrastructure. CZM and partners are embarking on a project to simulate sea level rise impacts on coastal wetlands to understand potential loss or redistribution of these important resources, and to carry forward the discussion about how to apply adaptation strategies and improve resource management to address potential impacts at the state, local, and parcel levels.

**Can Tidal Marsh Birds Persist in the Face of Climate Change?**
Chris Field, PhD Candidate, University of Connecticut; Chrisfield22@gmail.com
*(co-authors: Elphick, C.S., T. Bayard, S. Meiman, J. Hill, C. Gjerdrum, and M. Rubega)*

Saltmarsh sparrows are vulnerable to global extinction as a result of sea-level rise. In the near-term, increased tidal flooding will likely make reproduction impossible; in the long-term, the extent of nesting habitat – *Juncus gerardii* and *Spartina patens* – is likely to be greatly reduced. Potential conservation actions focused on the sparrow – such as sediment nourishment, tidal flow restoration, or tree-cutting at the marsh edge – are likely to be expensive and in some cases their effectiveness is largely unknown. For example, many millions of dollars have been spent on tidal marsh restoration throughout North America, and Southern New England has a long history of tidal marsh restorations, largely focused on the removal of the invasive plant *Phragmites australis*. We found that saltmarsh sparrows had significantly lower abundance and nest densities at sites where tidal flow had been restored than at either reference sites or sites with direct *Phragmites* control. We conclude that, although tidal marsh restoration removes *Phragmites* and restores native marsh vegetation, it produces habitat that is unsuitable for saltmarsh sparrows. No abundance differences were found for other focal taxa (large wading birds, willets, seaside sparrow). However, these species may still be vulnerable to extinction as a result of increased tidal flooding and habitat loss from sea-level rise, albeit over longer timescales than saltmarsh sparrows.

**Salt Marsh Adaptation Strategies in Rhode Island in Light of Sea Level Rise**
Wenley Ferguson, Director of Habitat Restoration, Save The Bay, Providence, RI; wferguson@savebay.org

Under historic rates of sea level rise, salt marshes are able to survive by accreting sediment and organic matter at a rate comparable to sea level rise. Rhode Island has seen an increased rate of sea level rise in recent years. Rapid sea level rise may lead to erosion of the low marsh margin, and increased inundation and deterioration of the marsh surface. During a two year state wide salt marsh assessment, Save The Bay documented that Rhode

Island salt marshes are showing signs of marsh response to the effects of sea level rise including increased inundation and deterioration of the marsh substrate. This presentation will discuss adaptive management techniques currently being piloted or proposed to restore marsh hydrology affected by increased sea level. Techniques include hand digging small runnels or creeks, excavating clogged creeks using low pressure ground equipment, and raising marsh elevation with dredge material.

**Sea Level Rise Impacts on Salt Marshes: Implications for Coastal Zone Management in RI**
Caitlin Chaffee, Policy Analyst, RI Coastal Resources Management Council, Wakefield, RI; cchaffee@crmc.ri.gov

This presentation is a brief summary of the specific challenges facing coastal resource managers as a result of sea level rise impacts to coastal wetlands and how we are currently approaching them in Rhode Island. It poses two important questions: 1) How can we better use the information that we have? and 2) What additional information do we need to make informed management decisions? This should be a good starting point for the afternoon group discussions.

# The Effects of Sea Level Rise on RI's Salt Marshes

Wednesday, April 16, 2014, 9:00 a.m. - 3:30 p.m.
Save The Bay, Providence, RI

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## Comments, Q&A

### A Salt Marsh Retrospective for the Future

*Susan C. Adamowicz, Ph.D., Coastal Biologist, US. Fish and Wildlife Service*

C: Add plant ecologist George Nichols, published classification for tidal wetlands in 1920. Nichols described the phytosociological communities of tidal wetlands in 1920 and acknowledged that *Phragmites* was a component of the brackish tidal wetland but never described this grass as being invasive.

Q: You mentioned marshes will not really fully regain function until two or three decades after restoration. Do you know how this will impact preserved areas for marsh migration and sea level rise? Is it worth doing, are they really going to function well, will they have vegetation but loose function?

A: This topic can be discussed later. Marshes will migrate, we will see formation of ghost forests where trees die first but they are still standing. We can see this in Maine. There will be functionality only not to the full expression of it.

C: Regarding marsh migration, we have to keep in mind if there is land where to migrate to, especially in areas in RI, CT, and MA.

Q: We have mention function of salt marshes. Can you describe what it means?

A: Other talks will address this question, and if not, we can talk about this later in the question session.

### Vulnerability of Rhode Island Salt Marshes to Accelerated Sea Level Rise

*Elizabeth B. Watson, Ph.D., Ecologist, US. Environmental Protection Agency*

Q: Why do you think the ponding occurs in the center of the marsh rather than from the out border in, because you would think that is where the elevation would remain higher? Are there any specific sediment characteristics that contributed to the salt marsh sustainability? You mentioned that the previous input was from logging and other kinds of landscape activities that are no longer being conducted.

A: There was not much exchange in the marsh area associated with deforestation. I do think that in RI salt marshes only form this pond and so expecting them to be sustainable is not a term that is practical.

Q: Did you measure hydrogen sulfide?

A: No.

Q: Do you have any thoughts about the genetic component of the *Spartina alterniflora* harvested for your research and how they might have optimal growth at a different elevation?

A: In one of our greenhouse experiments, I did see that our specimens from Maryland seemed more adapted to above ground growth.

### The Declining Role of Organic Matter in Narragansett Bay Salt Marsh Accretion

*Joanna Carey, Ph.D., ORISE Postdoctoral Fellow, US Environmental Protection Agency*

Q: Are mushy sediment more susceptible to erosion than sediments that are mostly rock? It seems reasonable, but I was wondering if it has actually been tested?

A: I think it has not been tested for Narragansett Bay.

Q: You said your hypothesis is that rivers are not contributing much with sediment to the salt marshes. Do you think this is due to the urban storm water runoff and getting big pulses instead of continued erosion processes?

A: Interesting idea. If sediment comes out in one big pulse marshes might not be able to use it instead of continues slower supply.

### Dieback Events Accelerate Ongoing Spartina patens Loss in Rhode Island Salt Marshes

*Kenneth Raposa, Ph.D., Research Coordinator, Narragansett Bay National Estuarine Research Reserve*

C: Most influential factor for marsh dieback is yeast.

A: We have observed that marsh dieback on Prudence Island is not from yeast, crabs or wrack formation but from too much water staying on the marsh.

Q: Do you have any idea what ground water is doing?

A: We don’t know. However, the backside of Nag gets freshwater from the road.

**Developing a Salt Marsh Assessment Focused on the Impacts of Rapid Sea Level Rise**

*Marci Cole Ekberg, Ph.D., Coastal Ecologist, Save The Bay*

Q: Could you clarify the slide about prioritizing-green versus red? You said 'these are in good shape", but good shape in terms of what?

A: We looked at 40 different marshes and being in good shapes is relative to each other; good shape would be if it still maintains *Spartina patens*.

Q: Did you look at depth of peat versus depth of sediment?

A: We did not. Originally we looked at the root biomass. It would be an interesting parameter to add.

Q: Are the die-off areas related to their bearing capacity?

A:

Q: You mentioned that the marshes that are in worst shape are the ones we should focus our restoration efforts. This is something we want to talk about since if we cannot save them all, we might as well focus on the ones that are better shape in the green, instead of the ones in red or in not so good shape.

A: Potentially; however, it could be different strategies for each category.

C: This might be good discussion for the afternoon session.

**A GIS Assessment of Salt Marsh Change in Rhode Island from 1981to 2008**

*Meghan Nightingale, Wild & Scenic*

Q: When you did the delineation in the field the *S patens* zones where those dominated by *S. patens* or did you find transitional areas –a mix of *S. patens* and *S. alterniflora*?

A: Those zones were dominated by *S. patens,* no mix at the time.

Q: You mentioned there is an average of 71% increase in development around salt marshes. Do nutrients from development have an impact on salt marsh degradation, like from septic systems, for example? Did you grade areas that rely on septic systems versus sewage areas?

A: I did not.

Q: Did you look at *S. alterniflora* and *S. patens* change in coverage?

A: I could not delineate changes in vegetation with confidence in the images of 1981, so I didn't continue with the subsequent years. Perhaps if the images from 1981 were better…

Q: How do you identify a marsh since they are kind of continuous?

A: That is a great point and I struggled myself with that. However, delineating the vegetation was done to correlate with the sparrow population, and that's how we established limits.

Q: Did you look at other factors like migrations?

A: I might have looked at it but that was beyond the scope of my work.

C: Regarding vegetation losses, it is not only what you see above but also what is going on below ground. The root morphology of *S. patens* is quite different and more susceptible to water logging when compared to *S. alterniflora*. This is something to keep in mind when looking at mechanisms for losses and for future monitoring; for instance, marsh elevation which will make water logging very important.

**Salt Marshes and Sea Levels in Eastern Long Island Sound**

*R Scott Warren, Ph.D., Tempel Professor of Botany, Emeritus, Connecticut College*

Q: About the inundation tables, do you think there is a threshold when you start to see vegetation changes, let's say, in 25 or 50% inundation?

A: Inundation might not be the problem.

C: A number of species have a sea level rise curve that has to be taken with great deal of caution. The error is so large; it is suggested to look at longer tidal records instead.

Q: Was there a difference in marsh elevation between sites or slope?

A: There was a big difference in elevation, in terms of slope, they were gentle.

**Marsh Elevation Monitoring Efforts and Conservation Strategy Development by the Nature Conservancy on Long Island, NY**

*Adam Starke, Coastal and Marine Conservation Coordinator, The Nature Conservancy on Long Island*

C: I noticed that we hadn't really touched the ecosystem underneath the salt marsh. Salt marsh plants are not the only organisms living within the salt marsh and I think that looking at that in terms of monitoring and sea level rise is very important; the rib mussels may help with accretion, whereas the fiddler crab can help with erosion.

Q: I was wondering about the real estate tax used to purchase parcels for wetland migration, did you get pushed back from the communities that you are taking prime property out of the tax base?

A: I am not familiar with that section since that is more policy than science. However, from what I understand, not much.

**Can Tidal Marsh Birds Persist in the Face of Climate Change?**

*Chris Field, Ph.D. Candidate, University of Connecticut*

Q: Are seaside sparrows one of those marsh birds that will lay eggs a second time if they fail the first time around.

A: They will to a certain point. If they success and have time, they will try again too. If they cannot time the first high tide very well, they will all fail.

Q: You talked about how restoration is not necessarily so great for sparrows, how about restoration for some of the seaside sparrow you studied?

A: There were no difference between control and *Phragmites* restored sites.

**Salt Marsh Adaptation Strategies in Rhode Island in Light of Sea Level Rise**

*Wenley Ferguson, Director of Habitat Restoration, Save The Bay*

C: When we go to communities and talk about sea level rise affecting marsh migration, I ask our partners not to highlight the sediment deposition technique as something we will start doing on every other project. We need to be cautious with this approach. We are working with Fish and Wildlife Refuge, and they are considering it as a very control technique to try to increase the elevation based upon what we heard today. They are very concerned about maintaining the habitat in the marshes in the refuge property. We are not promoting this technique; because it is filling. We need to ensure that this is not done in a way that can promote anything but a healthier marsh.

**Sea Level Rise Impacts on Salt Marshes: Implication for Coastal Zone Management in RI**

*Caitlin Chaffee, Policy Analyst, Rl Coastal Resources Management Council*

Q: Your projection based on migration, and people that had lost a lot of land, can you comment on that?

A: I think that the take home is that we need treat model results with a grain of salt and look at what is happening on the ground. We have been doing that with the SLAMM effort. As we continue groundtruthing, we will have more and more information.

Q: Sea level rising is happening, how does it translate into horizontal in the salt marsh? Are we seeing that?

A: It would be an interesting thing to look at. I think that whether it is part of SLAMM effort or restoration strategies, having more accurate elevation data would help.

C: The results from SLAMM show there are challenges with the migration, I feel that region wide in our watershed there are more potential for migration in Taunton and Palmer. We are seen inland edges moving inland.

## What management questions related to salt marshes and sea level rise can researchers help to address?

What parameters can help us identify marsh migration areas?

- Involve social scientists and remember how people will respond
- What are the benefits of marshes? How can we best educate the public?

Forested areas and thick *Phragmites* stands that border marshes

- Which areas of vegetation should be protected and which should not?

What is happening in the subtidal areas?

What will be the impact of planted material/placement of sediment?

- Impact on vegetation
- Impact on species diversity
- How much should be planted/raising elevation

What are the results of restoration practices?

- Use caution
- Follow-up

What are the fundamental drivers of marsh accretion?

- Know what the problem is

What can science tell us about successful restoration practices?

What is the goal for marsh restoration?

- Understanding the effects of restoration
- At what scale should we be concerned?
- Restoration or sustainability? Marsh management?

Funding sources?

## What salt marsh monitoring strategies should be prioritized?

- More quality data
- Define monitoring vs. assessment (done on a regular interval, repeatedly over time with the goal of looking at change)
- Carefully choose what is monitored and how we monitor it
- Look at what parameter we want to focus on over space and time (the RI Salt Marsh Assessment (RISMA) is doing this, along with identifying adaptive management opportunities)
- Three-tiered template (hybrid approach)
    - Tier 1: broad-based mapping effort
    - Tier 2: RISMA (suggestions):
        - Belt transects (description of plant community); also useful for Tier 3
        - point intercept would be useful for targeting high marsh
        - bearing capacity
        - iris tube (for measuring hydrogen sulfide); turns black in a degraded marsh (more hydrogen sulfide)
        - elevation (RTK, SETs (proposal to add more)); site-based information
        - tide station data (frequency of inundation)
        - climate modeling (precipitation, run-off, ponding, groundwater, ocean acidification)
        - further classification
        - catastrophic events
        - network of real-time cameras in the marsh
        - ecotone monitoring/transects (extending into upland)
        - biomarkers
    - Tier 3: look at things more intensely
- Use existing data to do further analysis
- Establish best practices, standard protocols that everyone follows; aggregate into a database (grad students would benefit from this)
- Keep tidal marsh obligate birds in mind; if the vegetation is okay, usually the birds will be okay
- Strictly define what a healthy marsh is; it is important to know what it looks like
- Look ahead and keep in mind “What policy is this going to inform?”

## How do we prioritize restoration opportunities (both existing strategies and new approaches) considering time and funding limitations?

- NOAA Coastal Services Center is developing a climate change vulnerability assessment tool (CCVATCH) that could be used for prioritizing allocation of resources (http://www.northinlet.sc.edu/stewardship/CCVATCH/Pilot.html)
- We need to think about what we're restoring to; what's the functionality we're trying to maintain? Maybe we're going to give weight to certain elements, and there are different ways to achieve that; what is the restoration goal?
- What is the definition of restoration? Is what we're talking about restoration?
- What do you restore from? Do we triage or just focus on the ones we can save?
- Need to set the bar or timeline to establish a starting point, and restore function, but adapt for changing conditions
- We will not be able to go back to historic condition
- We have to look at what realm it is – private or public, who's funding, bang for the buck, scale; the bulk of what CRMC permits is privately owned and the majority is *Phragmites* and it will always be that; the vast majority of the work is residential, so we need a cost/benefit analysis
- We need to set goals, but those goals will probably vary depending on the area and context
- We need to devise scenarios of action/inaction, and a system approach
- We need to follow the lead of the eelgrass folks, and do regular monitoring of our salt marshes
- That is being done using our last eelgrass mapping images, so if we can advocate for 2-in-1 because those eelgrass images are so important, but they also have other uses
- Can we tie that to the SLAMM work? (might show priority areas; work to keep undeveloped land undeveloped
- Can we learn from Vermont which looked at keeping a river's sinuosity and natural variation from cycle to cycle and setting up your buffers accordingly? Can we attach it somehow to property ownership to let them know it won't always be theirs, and some sort of compensation for when they do lose it? (VT Active River Areas (tool for developing variable regulatory buffers): http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/vermont/ara-map.xml)
- We want to look at the level of services created from some action; each one will provide some level of service at a cost; other areas are doing similar things- let's not reinvent the wheel in terms of prioritization of efforts; thinking about it is great, but coming up with the funds is a different story; we're looking at 4-5 years down the road when we get a new president; it's going to be hard for us to prioritize in terms of cost
- Get homeowners to work together, get them to front the funds and collaborate to make the projects bigger, less piecemeal, and have that be a criterion for projects getting the green light
- Financing is key; pockets are so deep on private side and not on the public side; resources that can be brought in are mind-boggling on the private side
- So how do we communicate it to homeowners that it's in their best interest?
- Need SOME SORT OF INCENTIVE
- What can we do to guard against this type of situation? Maybe it's a public/private partnership to not put it solely on the private property owners
- Enhance fundraising, target large restoration areas that look like they're potential habitat for species threatened (salt marsh and sea side sparrow)
- Adam Starke talked about the transfer home purchase tax, and it's a great idea; the homes along RI coast are regularly turned over; the time might be right to attempt something like this
- There was a bill proposed in MA- property tax surcharge, not a property transfer tax
- Has been achieved in Block Island and Little Compton, but we are not likely to see it elsewhere
- Marsh migration will happen and they need to go somewhere; not necessarily development, but will also impact other marsh communities- brackish, freshwater marshes- and it's also a loss of diversity; as we

think of goals, remember that these other community types are also at risk; we might want to target them for protection and restoration

- Head-of-tide dam removals could be brackish marsh in the future
- If it's about biodiversity, what does that get us? We need to explain why it's important to have biodiversity as an ecosystem service
- Let's not forget the League of Concerned Scientists map that shows our climate will be similar to NC by 2100, so we need to protect the stage / physical landscape features, not the characters
- Consider adding the river herring to the Endangered Species list, and looking at species that can help us, looking beyond the salt marsh for rarer species that need protection
- Focus on public health (mosquito breeding, for example) to build community support
- Is there a goal towards protecting larger areas, and letting smaller ones go? What is the goal?
- Not so much size, but not piecemeal
- Linkage in ecological corridors
- Do we want to prioritize marshes where we see potential for migration?
- Who will achieve and respond to these goals?
- As a state agency with funding for these projects, CRMC depends on others to carry them out (Save The Bay, TNC, etc.); CRMC doesn't have a division of ecological restoration in RI- in reality, the projects that get done are the ones seen as important; it's helpful for us to have well-defined criteria, but it's a bottom-up process; so it's how do we engage at the local level?
- Areas that can migrate should be a priority
- Potential for migration would have impact on the lifespan of a project
- I am so optimistic and positive of what I'm hearing, and I'm convinced we as a community will succeed if we come up with a common vision
- Don't we also have to recognize that there are others thinking about sea lever rise and climate change who have nothing to do with the ecology and science, and everything to do with politics and economics?
- I agree but we will also have opportunity to restore where a road needs to come out or something like that; look at infrastructure
- Long Island Sound has done an ecological benefit analysis ("The Trillion Dollar Sound"), so it is possible to put a figure on it
- Educate the public, bring together watershed groups and locals who could be advocates
- What is the value of *Phragmites* in restoration projects? Does it have some value for accretion? This is an information gap

# Narragansett Bay National Estuarine Research Reserve Sentinel Site:

## Effects of Sea Level Rise on Salt Marshes




### PURPOSE

Salt marshes in Rhode Island currently face multiple threats, including increasing rates of sea level rise combined with years of anomalously high tides. If marshes are unable to keep up with rising sea levels, these wetlands will likely be impacted by shifts in vegetation, high marsh ponding, creek sloughing, and eventually, drowning.

Long-term monitoring data are important if we are to understand the comprehensive impacts from this projected inundation, and if coastal managers are to be successful in their attempts to protect and restore marshes from further climate change-induced degradation.

Although some monitoring components date back to 2000, new data sets on marsh responses to sea level rise are now available, thanks to the Research Reserve's Sentinel Site observations, which became fully operational in 2012. This Research Reserve, located on Prudence, Patience, Hope, and Dyer Islands in the geographic center of Narragansett Bay, represents a partnership between NOAA and the State of Rhode Island's Department of Environmental Management.

### SENTINEL SITE INFRASTRUCTURE

Monitoring infrastructure is located in the Coggeshall and Nag salt marshes, which are prime examples of intact mid-bay salt marshes. These sites will serve as long-term sentinel sites to evaluate how natural salt marshes change over time in response to global climate change and sea level rise. The infrastructure to collect observations includes tools to monitor vegetation, water levels, and elevation.

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### MONITORING TOOLS

- Six vegetation monitoring transects (three in each marsh) stretch from estuary to upland to quantify changes in marsh vegetation structure over time.
- Twelve surface elevation tables (six in each marsh) are paired with marker horizons to track salt marsh elevations and accretion rates over time.
- Hydrology and sediment monitoring instruments quantify water table levels, salinity, and sediment characteristics within both salt marshes.
- New water level logging stations—tied to the North American Vertical Datum of 1988 (NAVD 88)—quantify water levels over time and ultimately derive localized tidal datums for each marsh.
- A local vertical control network, including new elevation benchmarks, aligns all marsh elevation data with NAVD88, the official vertical datum in the National Spatial Reference System for the conterminous United States and Alaska.
- Elevation data are gathered using real-time kinematic GPS and Leica digital leveling equipment to confirm the stability of monitoring infrastructure and track changes in the elevation of marsh habitats over time.
- Annual monitoring of nekton, or free-swimming aquatic animals, tracks responses of resident fishes, crustaceans, and mollusks to changes in marsh conditions.
- A water quality station (from the System-Wide Monitoring Program) in Nag Marsh and a reserve weather station at nearby Potter Cove provide complementary water quality and meteorology data.

### OUTCOMES

- Enhanced local tidal datum and estimated rates of relative sea level rise
- Improved understanding of effects of increasing rates of sea level rise on Rhode Island salt marshes
- Estimates of salt marsh accretion rates to determine if marshes are keeping up with sea level rise
- Reference marsh data to evaluate the success of numerous restoration projects throughout Narragansett Bay, particularly those undertaken by the Research Reserve's partner Save The Bay
- Improved collaboration with local scientific and management partners also working in salt marshes

**PARTNERS:**

NOAA National Estuarine Research Reserves
NOAA National Geodetic Survey
NOAA Center for Operational Oceanographic Products and Services

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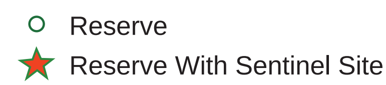
## NERRS Sentinel Sites



# Marsh lunacy: the role of the metonic cycle in vegetation change and the eroded edge.

Ron Rozsa[1] and Scott Warren[2]

1 CT DEP Coastal Management Program, 79 Elm St. Hartford, CT 2 Connecticut College, 270 Mohegan Ave, New London, CT

## Introduction

The classic vegetation paper by William Miller and Dr. Frank Egler on the Wequetequock-Pawcatuck Tidal Marshes (aka, Barn Island) in southeastern CT is the paradigm for southern New England salt marsh complexes (i.e., polyhaline chemistry is present throughout except along margins were oligohaline to mesohaline chemistry is present). These authors state: "the present mosaic may be thought of as a momentary expression, different in the past, destined to be different in the future, and yet as typical as would be a photograph of moving clouds" (Miller & Egler, 1950).

Miller & Egler (1950) described the 'eroded edge' of vegetation along the upland border. This 'dieback' was witnessed by Warren and Rozsa in the 1980's and in 2008. The eroded edge was also described in the 1960's by Gross (1967). It appears that the eroded edge is but a phase of marsh change that occurs every 20 years in a predictable manner and results from sea level rise variation in the **metonic** or **lunar nodal cycle**.

The eroded edge (early stage?) at Brucker Marsh in 1947.

The eroded edge/path (early stage?) at Headquarters Marsh in 1967.

The eroded edge/path at Headquarters Marsh in 1983.

The wide eroded edge at Brucker Marsh July 2008

The

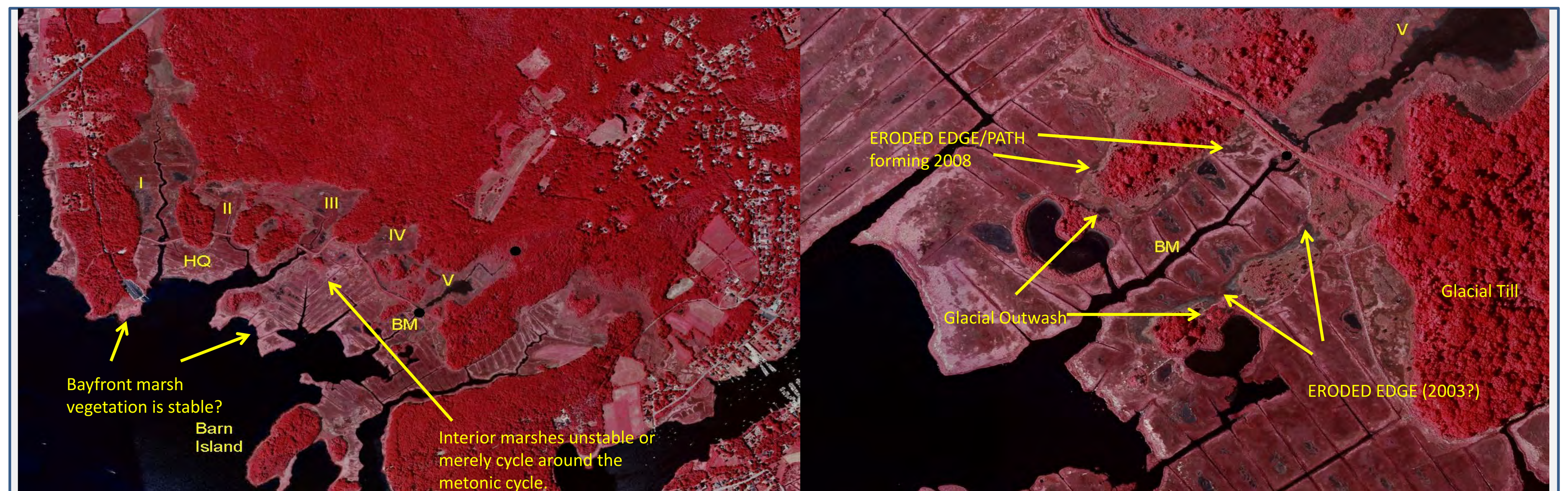
## Materials & methods

**MATERIALS AND METHODS:** At this stage of this investigation, the chief method is forensic ecology (e.g., mining plant community data from several Masters Thesis and peer reviewed articles; historic photography including aerial photographs; personal observations past and present). High resolution LIDAR data is used to examine marsh microtopography and NOAA tide data from the nearby New London tide gauge are used to examine the relationship between tides and vegetation change.

## Results

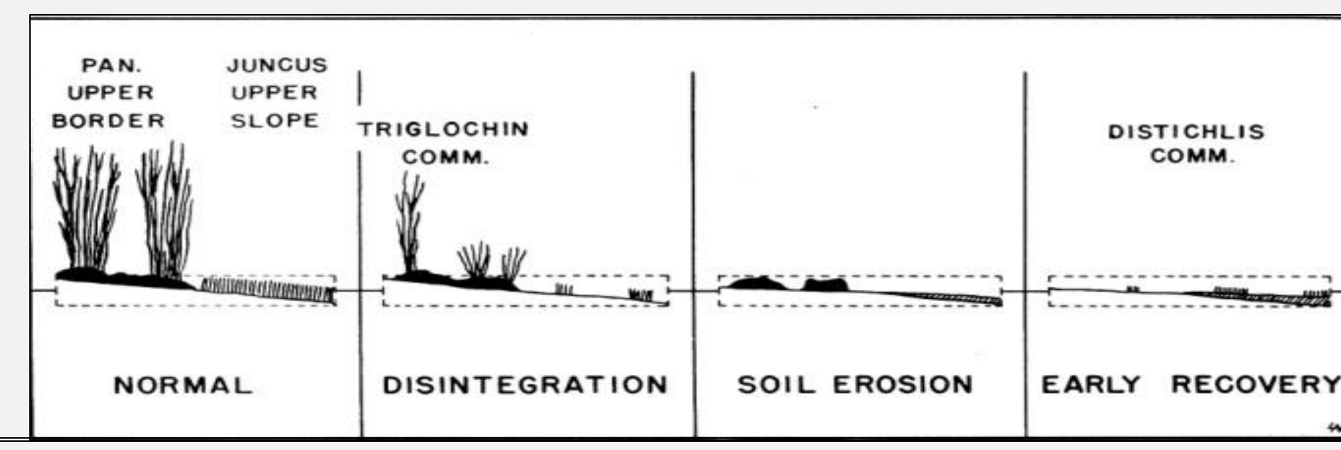
The position of *the Panicum virgatum* belt on Headquarters Marsh appears stable since 1948. However, the same community on Lower Brucker and Davis Marshes is shifting landward. The Eroded Edge, constituting less than 5% of the Tidal Marsh, is a belt of relatively bare peat which occurs between the limits of stunted *alterniflora* and within portions of the *Panicum* Belt where severe erosion has occurred. This conspicuously bared area slopes gently down from the upland with its innermost portions grading into a slight panne-like depression. Scattered forbs tend to dominate the sloping peat, while *Distichlis* is predominant in the seaward depressions. On the basis of this pattern, both a Forb and a *Distichlis* Phase are recognized. The Forb Phase is dominated by *Plantago* and *Triglochin*. Very little litter is found among plant stems, supporting the model that erosion is an important factor here and that deposition is minimal. The *Distichlis* phase is usually only encountered in the Lower Marsh, adjacent to the stunted *alterniflora* in the slightly lower depression of the Eroded Edge. (Miller & Egler, 1950)

Miller and Egler argued that mowing was an important factor producing the Eroded Edge: "Various phenomenon of (a) community disintegration, (b) sheet erosion, and (c) revegetation of the Upland Border of the Upper Slope are here interpreted in terms of excessive mowing. It is to be understood that this explanation is strictly an interpretation, believe in accord with our contemporary knowledge in the fields of range and pasture management and soil conservation … mowing history described … At the present time, one part of the Brucker Marsh is mowed, and it here that the effects are most conspicuous" (Miller & Egler, 1950).




Along the seaward borders of the Brucker marsh, the vegetation is thin, scanty, or absent in a belt easily correlated with the normally dense Panicum Upper Border and Juncus Upper Slope. Observation quickly discloses the dead or decadent bases of plants normally growing in tussocks, especially *Panicum virgatum*, also *Triglochin* and *Plantago*. …. The fact that *Triglochin* becomes abundant may be of considerable practical importance, as this plant is a species known to be poisonous to cattle and other stock." (Miller & Egler, 1950)

Fig 18 from Miller and Egler (1950). "…effects of mowing on the upper border and upper slope, interpreted from historical and contemporary conditions."

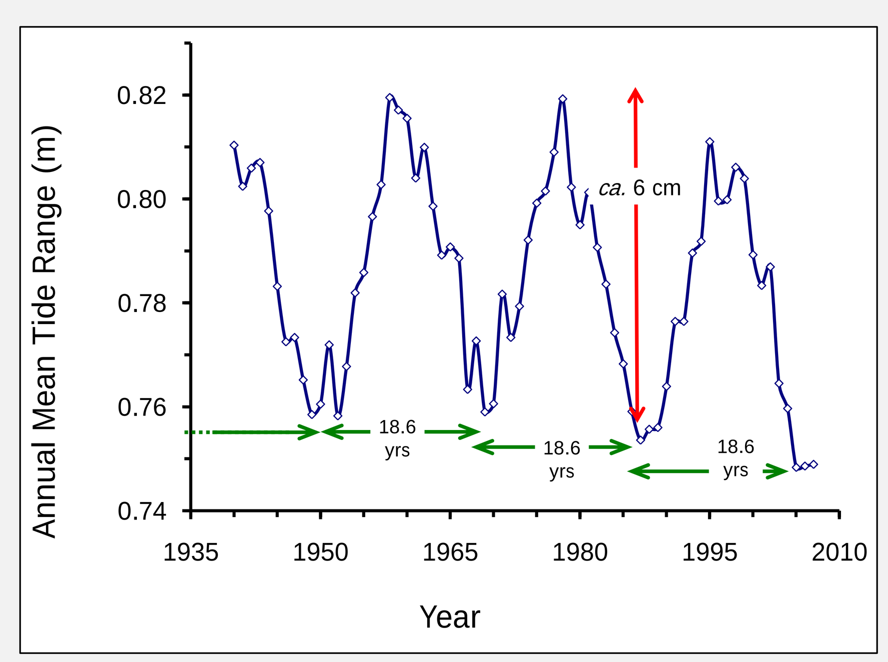


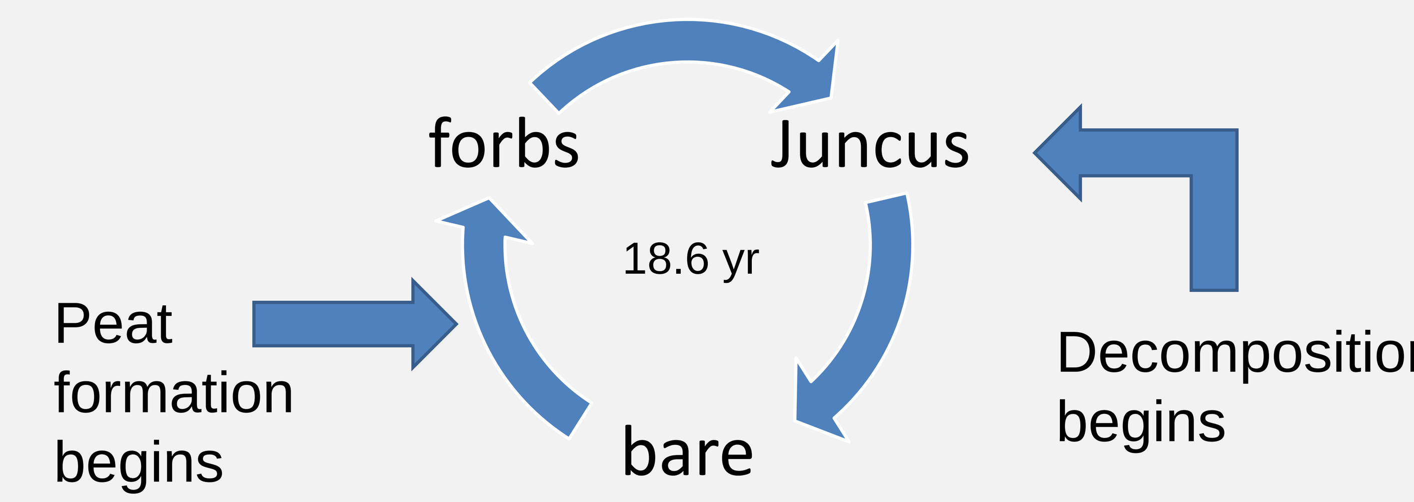

Almost 20 years later Gross (1968) reported the presence of the eroded edge from field work in 1966-1967 at BM. "The position of the *Panicum virgatum* belt on Headquarters Marsh appears stable since 1948. However, the same community on Lower Brucker and Davis Marshes is shifting landward." (marine transgression? – comment added). Gross further noted that "Egler and Niering have found the *Juncus* belt to be replaced by arrowgrass on parts of the HQ marsh … They feel that the impacts of man's trampling as he walks along the upper edge of the marsh may be important in contributing to the decrease in *Juncus*."

Blake-Coleman report no edge phenomenon in 1976, *Triglochin* had replaced the *Juncus* belt at HQ and remarked that *Juncus* appeared to be expanding. By 1983, Niering, Warren and Rozsa would find the Juncus belt had returned to HQ but was beginning to form a trail. By the late 80's the HQ *Juncus* belt had become characterized by forb panne vegetation and in the 1990's would be dominated by severely stunted *Triglochin* and *Limonium*. This pattern was seen throughout CT marshes in the 1980's including areas with no pedestrian traffic.

The eroded edge returns to BM and the "path", first recognized by Niering and Egler (1965), is beginning to form along HQ marsh in a zone of *Triglochin* and *Juncus* during summer 2008.

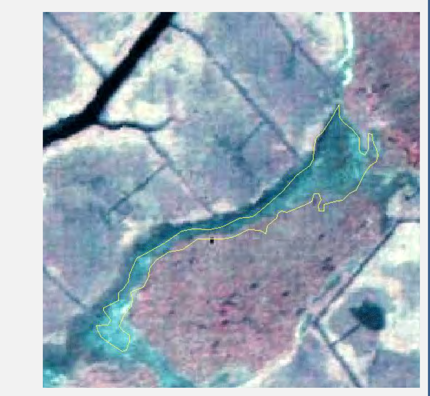
During the metonic cycle (18.6 years), high tides increase for 9 years and then decrease for 9 years. The variation in amplitude at New London was nearly 11 centimeters. Depth and duration of flooding increase for 9 years and then decreases for 9 years. Groundwater table likely follows the metonic cycle trends. The eroded edge was present in 1947, 1965, 1983 and as earlier as 2003. These times are just before the lowest of the tidal range.




The *Juncus* belt can reform in less than 6 years as the tidal range or sea level rise are increasing but upon entering the cycle as the range decreases and tidal elevations drop, the *Juncus* belt degrades. In the recent BM dieback, the peat is absent exposing the underlying outwash sands suggesting this is the marine transgression peat built in the decade of the 1990's. As sea level rises, the soil becomes anaerobic and the peat building phase begins with the establishment of forbs.

The area of the 2008 eroded edge is shown to the right overlying the 1980 aerial photograph. The eroded edge appears to occupy what was former uplands dominated by *Panicum virgatum*. The depth of peat is about 8 centimeters. The photo to the right shows a section of peat & vegetation that has not yet 'eroded' with a tripod leg for reference. The wet phase of the cycle creates new peat and the dry phase creates aerobic soil conditions leading to peat decomposition and erosion of soil. It is possible that groundwater discharge is contributing to the soil 'erosion'.



## Conclusions

These data and field observations demonstrate that some of the vegetation change on tidal marshes are cyclic and occur on a ~20-year cycle. The most likely driver is tidal variation in the metonic cycle. The data suggest that variation in vegetation response may be due to differences in surficial geology and ground-water (drainage?). As the eroded edge forms marine transgression of high marsh plants especially *Juncus* into the uplands occurs while stunted *S. alterniflora* expands into the high marsh zone. The 'edge' cycle progression is vegetation loss, colonization by forbs especially *Triglochin* and *Plantago*, development of a *Juncus* belt and return of the eroded edge. The edge plants affected include *Panicum virgatum*, *Juncus gerardii*, *Spartina patens* and even *Iva frutescens*. Plans are under development to install SETs, water table wells, and permanent transects to capture the changes that occur in the next 20 years. Cows and mowing have not occurred since at least the early 1960's particularly at BM.

## Literature cited

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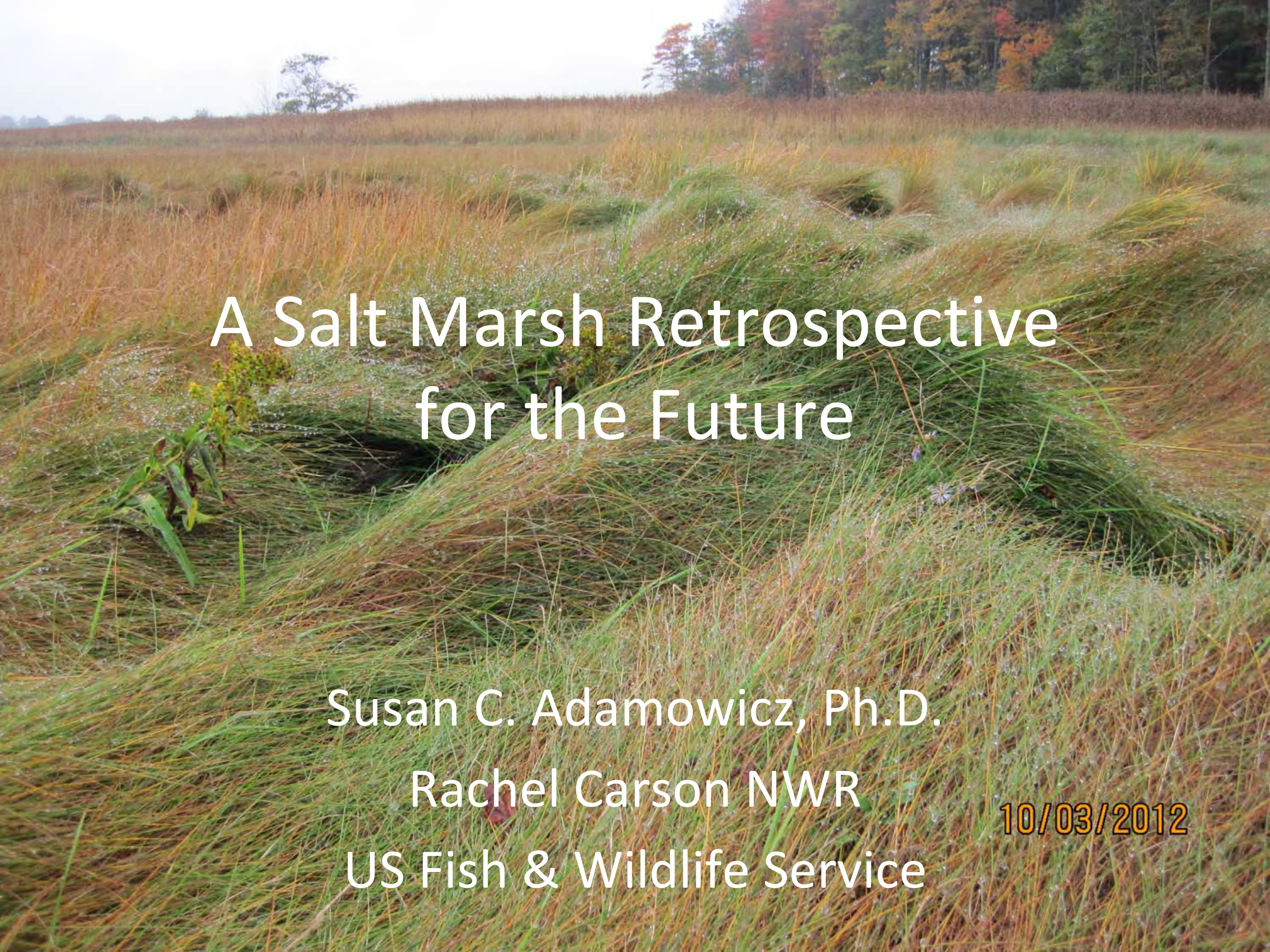
Gross, A.C. 1968. Vegetation of the Brucker Marsh and the Barn Island Natural Area, Stonington, CT. Unpublished M.A. Thesis, Connecticut College, CT

Miller, W.R. & Egler, F.E. 1950. Vegetation of the Wequetequock-Pawcatuck tidal marshes. Ecological Monographs 20, 143-172.

Warren, R.S. and Niering, W.A. 1993. Sea level rise and vegetation change on a northeast United States tidal marsh. Ecology 74:96-103.



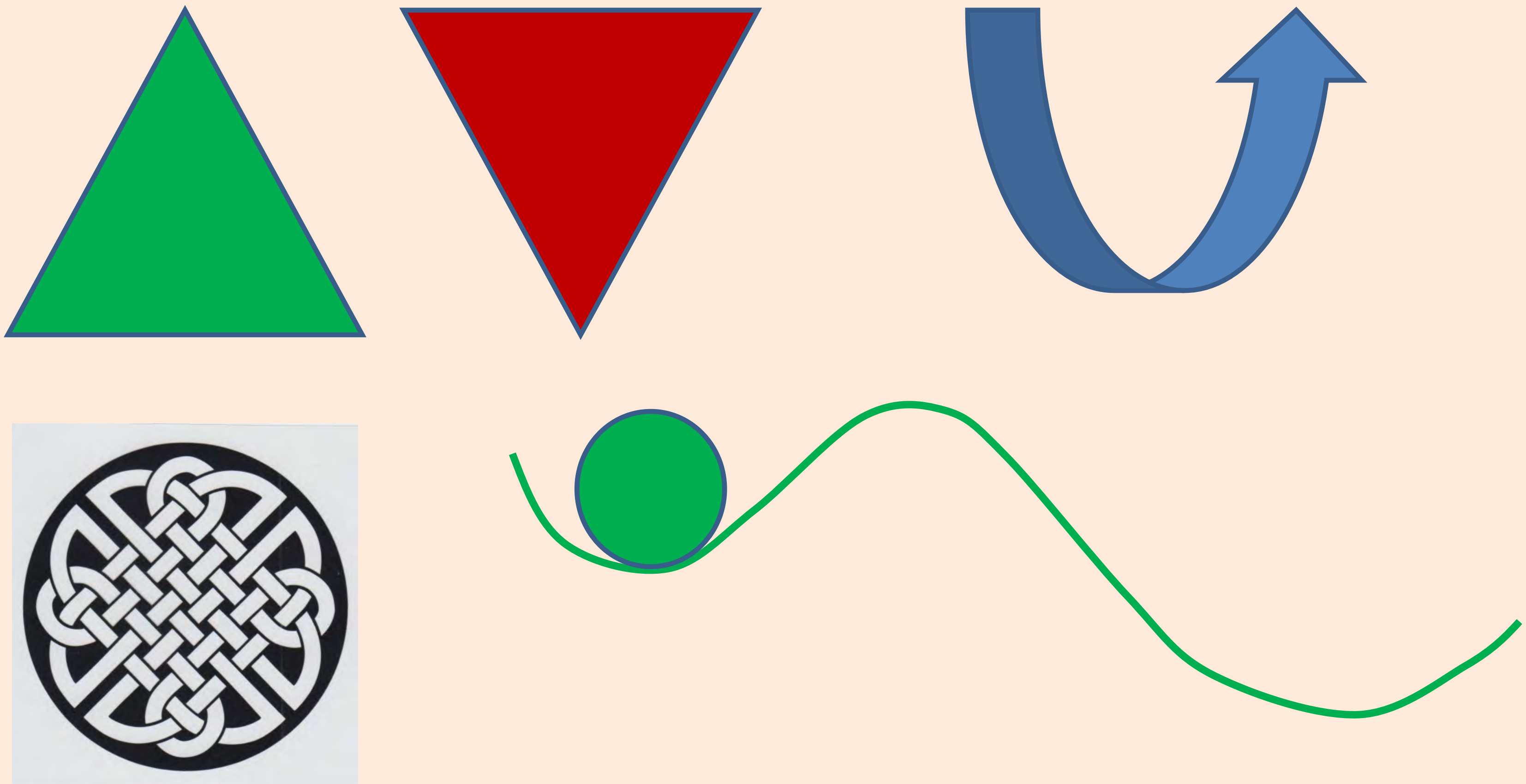

# A Salt Marsh Retrospective for the Future

Susan C. Adamowicz, Ph.D.
Rachel Carson NWR
US Fish & Wildlife Service

# Items for Your Consideration

- What we know shapes what we see
- Salt marshes are not only a product of abiotic and biotic interactions but also of their history
  - We will go on a walk through history…a wrinkle in time
- Highlight what's to come in terms of challenges and ideas
  - Things are not necessarily as they seem

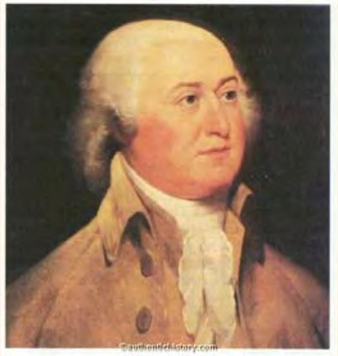
# Metaphors We Carry



# Time Spent in Conflict

| 1620 | 1754-1763 | 1775-1783 | 1812-15 | 1861-1865 | 1914-1918 | 1941-1945 |
|---|---|---|---|---|---|---|
| Mayflower @ Plymouth | French & Indian War | Revolutionary War | War of 1812 | Civil War | WWI | WWII |

# Post-European Settlement



John Adams by John Trumbull; wikitree.com

Goethe

1620 — Mayflower @ Plymouth

1754-1763 — French & Indian War

1771 — Salt hay ditches

1775-1783 — Revolutionary War

1790


Map next slide

1800

1812-15
War of 1812

Grazing
Salt hay paper

1848
Drakes Island dike

1859
Darwin

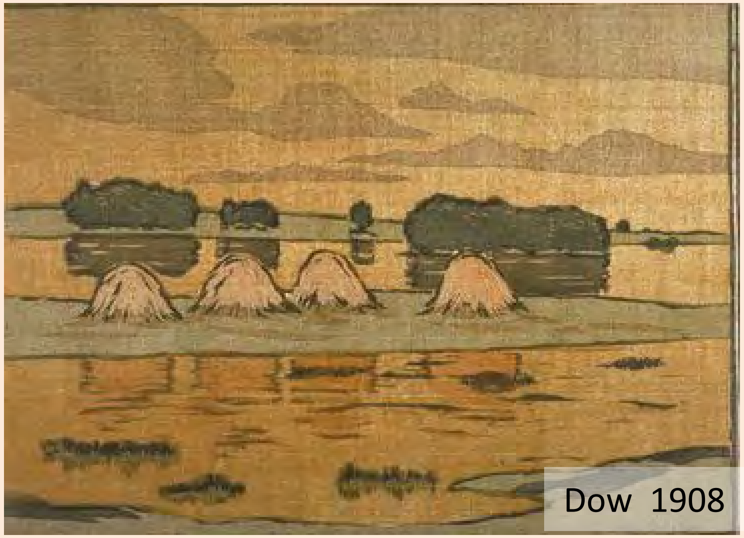
1861-1865
Civil War

1862

1880

1886

# Marsh Ownership 1886



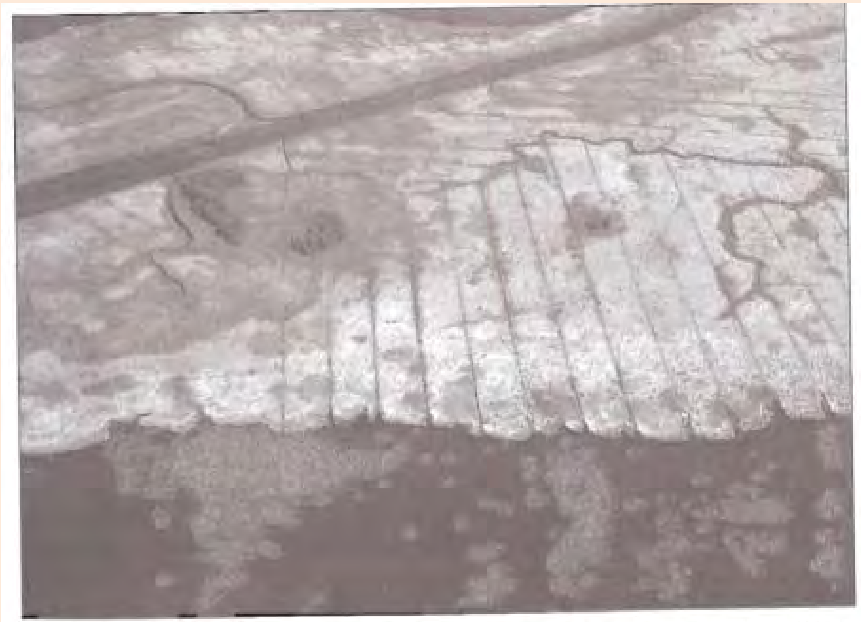
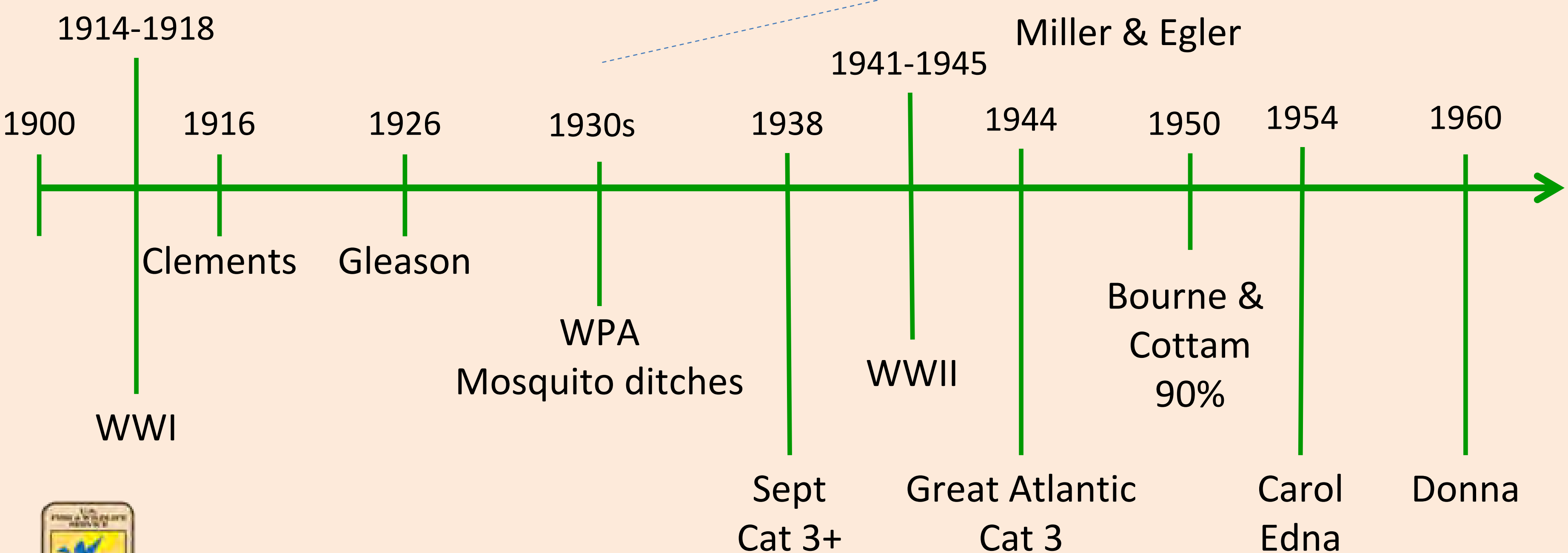
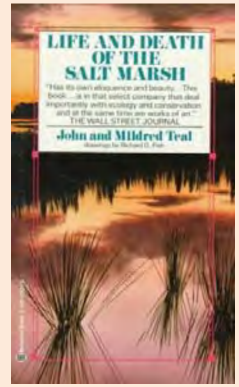
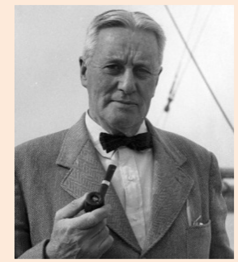



Fig. 4 The extent of mosquito ditching is best seen in aerial photographs. (DEP OLISP)



Ice Skating on Palmer River Salt Marsh



Teal

1962

Ferrigno & Jobbins

1968

Teal$^2$

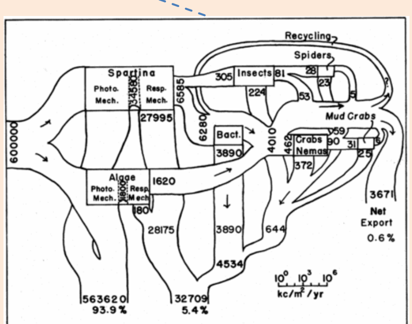
1969

1970

Redfield

1972 1973

Silent Spring




OMWM

DDT sprayed
Barrington, RI

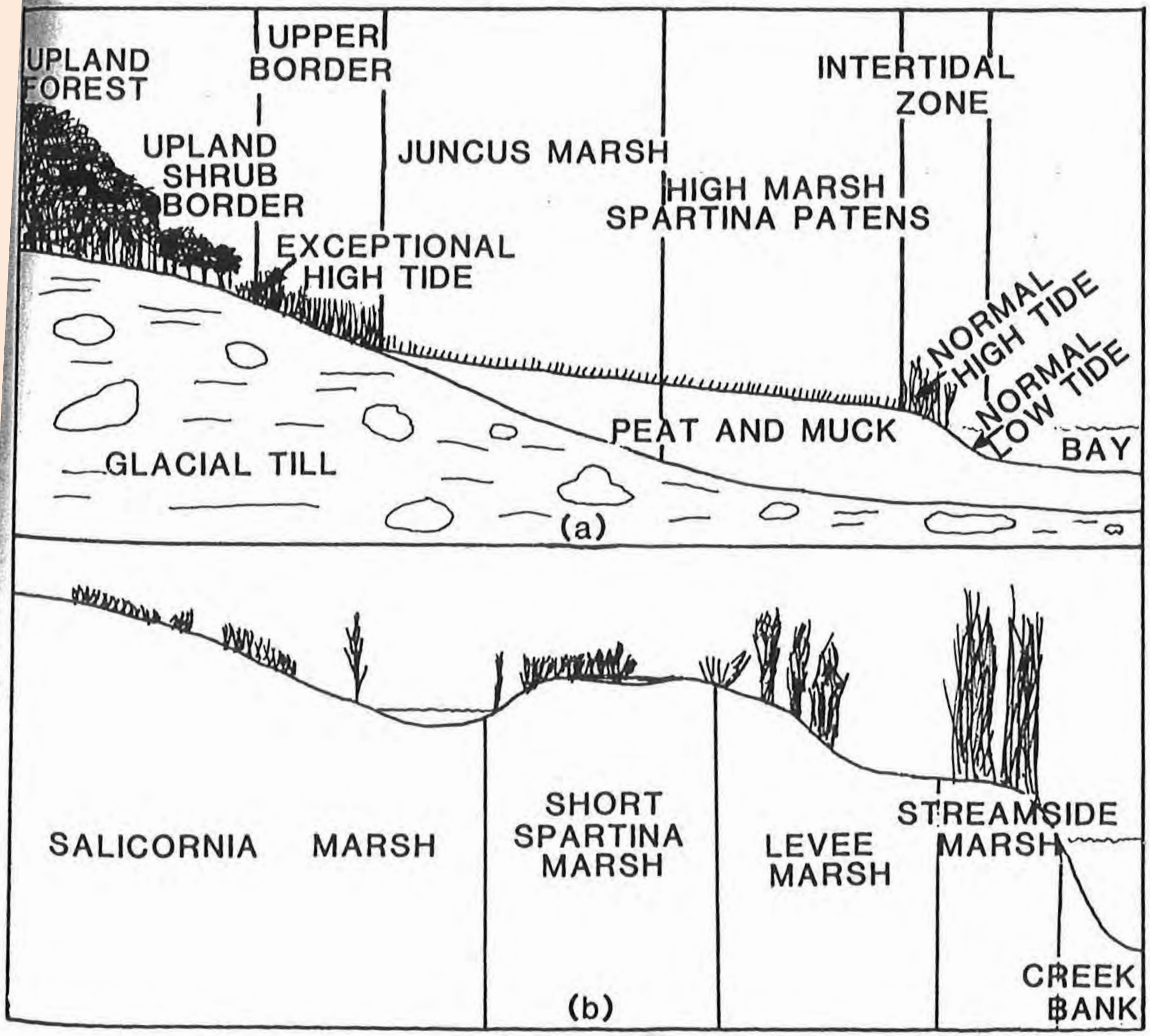
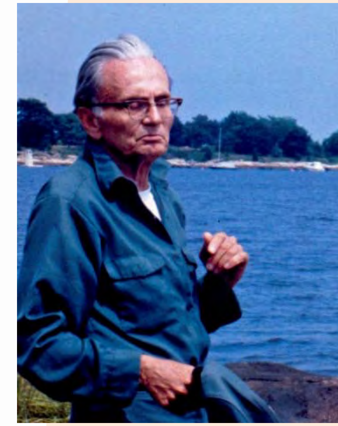
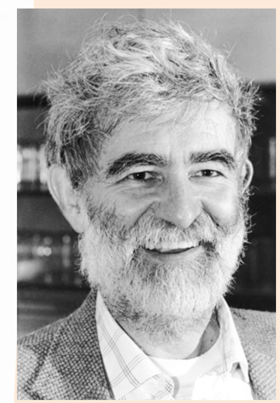
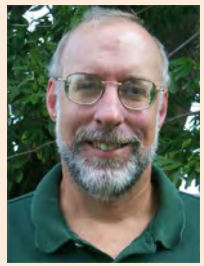



**Figure 8-6.** Zonation of vegetation in typical North American salt marshes. *a.* New England salt marsh *(after Miller and Egler, 1950, p. 155; Copyright © by the Ecological Society of America, reprinted with permission). b.* Georgia salt marsh *(after Teal, 1962, p. 616).*







Nixon & Oviatt
1980
Niering & Warren

Allen & Starr
1982
Hierarchies

Roman Niering Warren
1984
Tidal Restriction Effects

Pickett & White
1985
Disturbances
Gloria

1990
1st IPCC report

1991
Bob

Cahoon, Day, Reed
Odum³
Forman
1995
Pulsed Ecosystems
Land Mosaics

1999
Floyd

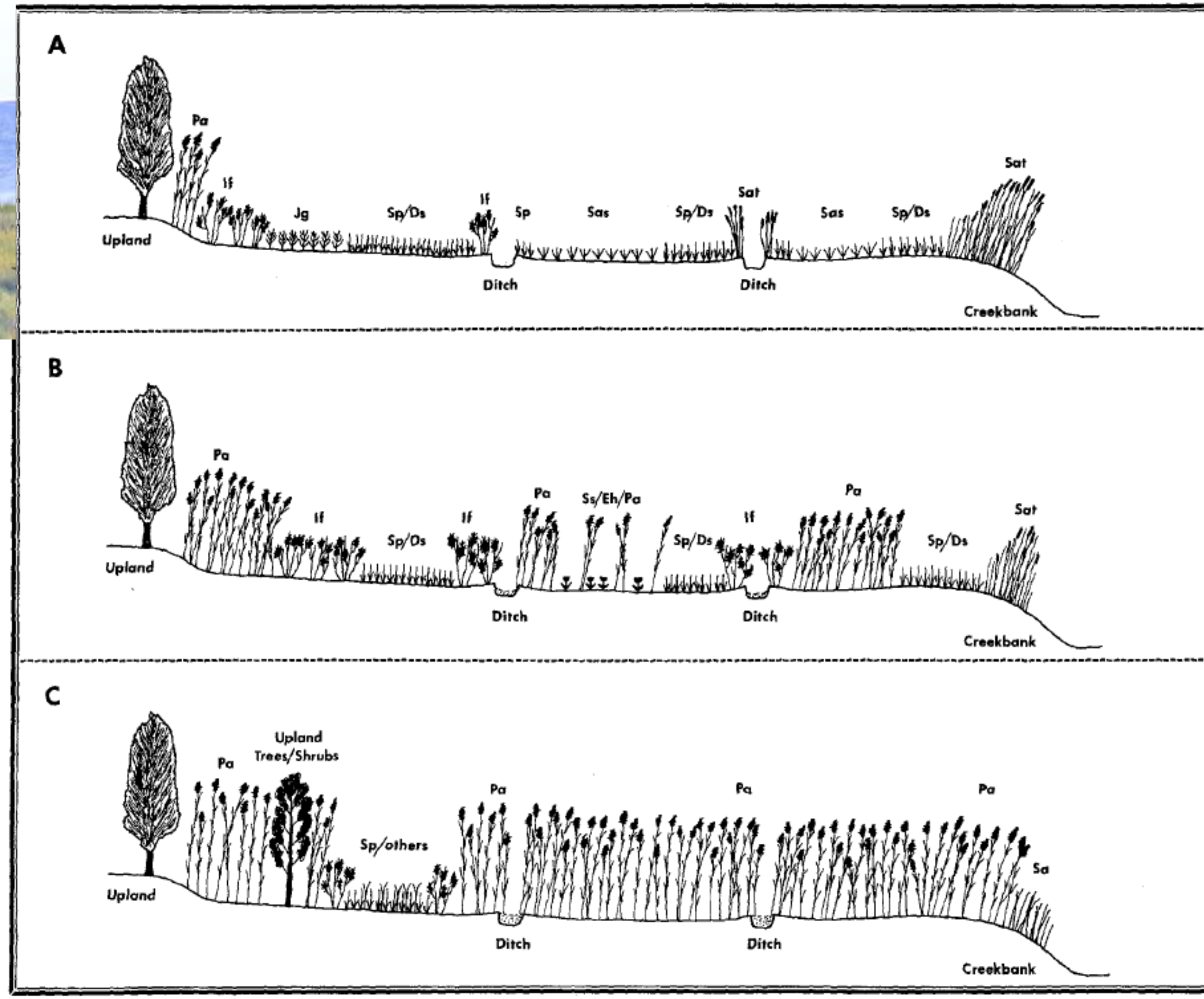
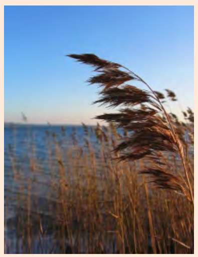



**Figure 4.** Schematic representation of vegetation change in response to tidal restriction along a creekbank to upland transect. (**A**) Vegetation patterns of a typical unrestricted southern New England salt marsh. (**B**) Restricted marsh at an intermediate stage of vegetational change. Note the invasion of *Solidago sempervirens* and *Erechtites hieracifolia,* and the increase in *Iva frutescens* along the ditches. *Phragmites australis* is encroaching from the upland border and "islands" are becoming established on the high marsh. (**C**) Fully degraded *Phragmites*-dominated restricted marsh. Note the narrow belt of *Spartina alterniflora* along the creekbank, the persisting *S. patens* area mixed with upland herbs and the invasion of upland trees and shrubs. Key to vegetation: Sat, Sas, *Spartina alterniflora* (tall) (short); Sp, *Spartina patens;* Ds, *Distichlis spicata;* If, *Iva frutescens;* Jg, *Juncus gerardi;* Pa, *Phragmites australis;* Ss, *Solidago sempervirens;* Eh, *Erechtites hieracifolia.*



2000

2001

Burdick
Buchsbaum
Holt

2002

Dieback Noticed

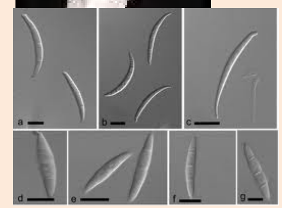
DiQuinzio et al.

2005

Katrina

Wigand
2008

Smith
2009

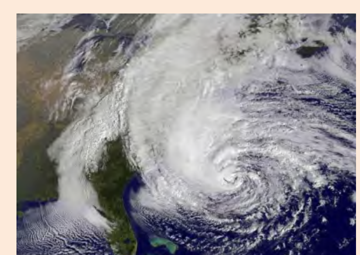


Elmer &
Marra
2011

Irene

2012


Sandy



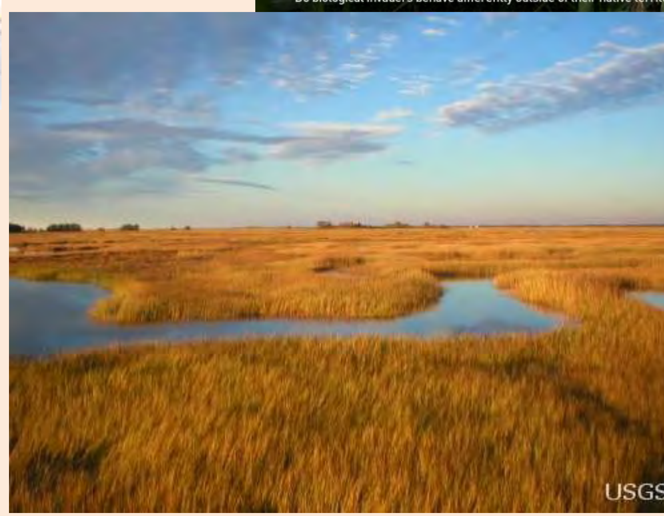
Rachel Carson
50$^{th}$ Anniv Death

2014

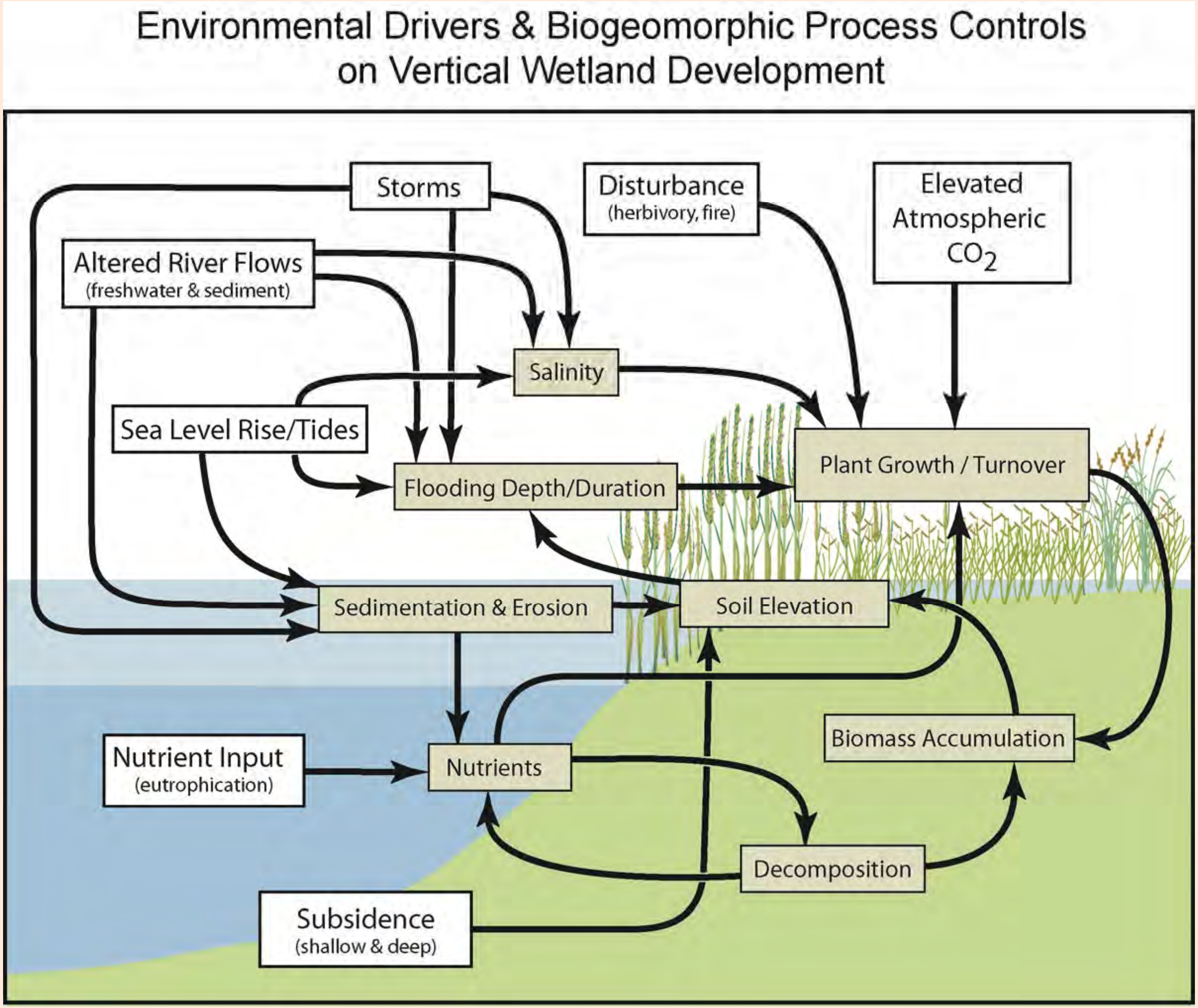
# Things are not as they seem

James Morris
Maximum Productivity Elevations


2002

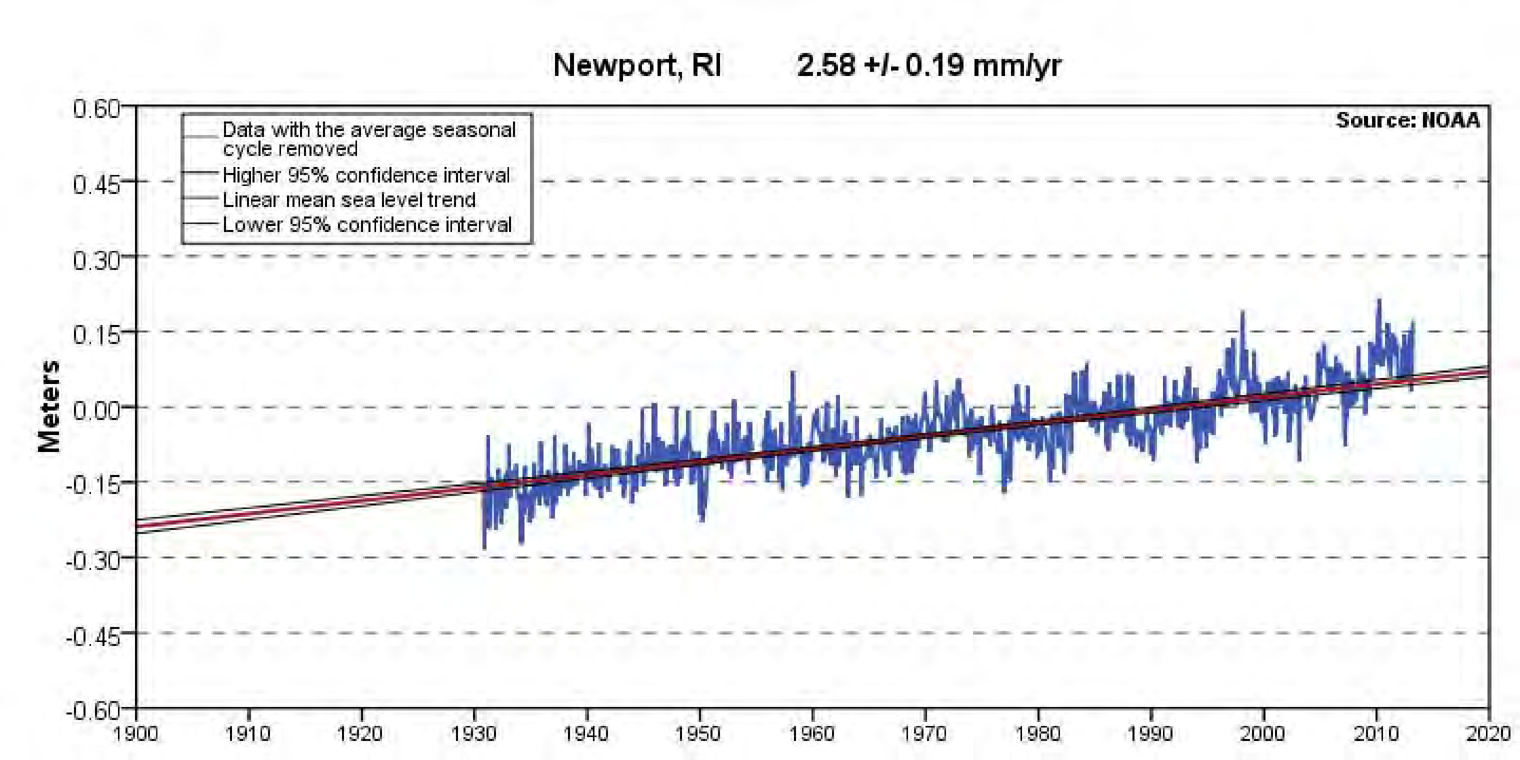


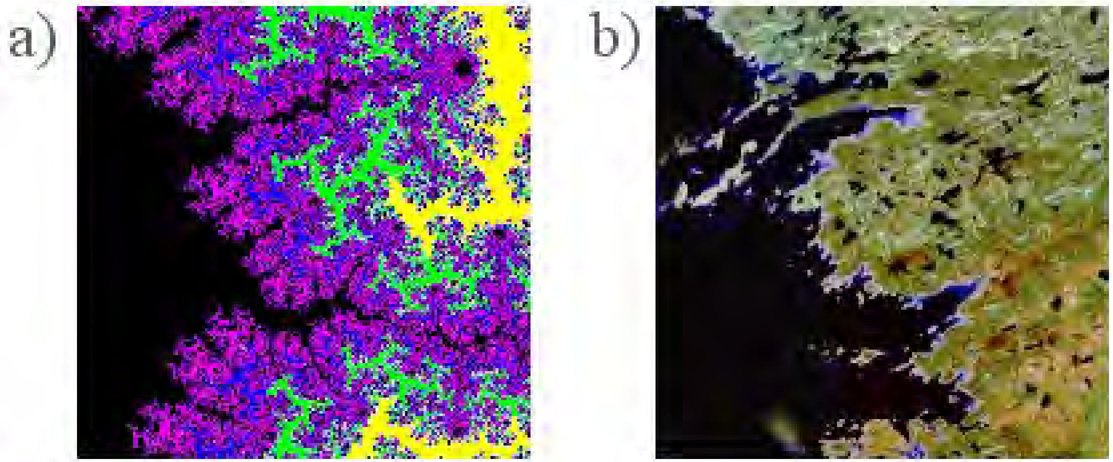

Kirwan et al. 2010


Environmental Drivers & Biogeomorphic Process Controls on Vertical Wetland Development
Storms
Disturbance (herbivory, fire)
Elevated Atmospheric $CO_2$
Altered River Flows (freshwater & sediment)
Salinity
Sea Level Rise/Tides
Plant Growth / Turnover
Flooding Depth/Duration
Sedimentation & Erosion
Soil Elevation
Biomass Accumulation
Nutrient Input (eutrophication)
Nutrients
Decomposition
Subsidence (shallow & deep)

# Other Patterns

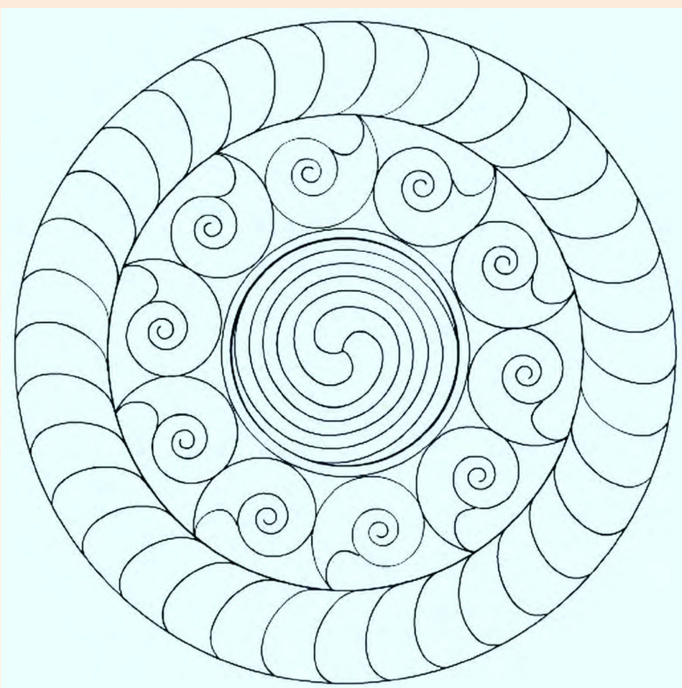
- Metonic cycles
- Marine transgression/ marsh migration
- Climate change: rainfall patterns & currents






a) Part of the Mandelbrot set.

b) Part of the North American coastline near Hudson Bay.



# Why is all this important?

- We are off to uncharted territory
- Historic alterations may play a significant role in how salt marshes respond
- Restoration/ resiliency is like picking a lock – you need to hit all the right tumblers

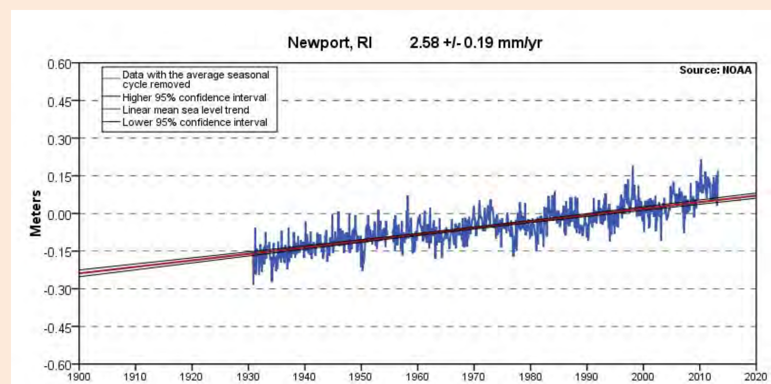
Marsh Vulnerability

Watson

Narragansett, RI


Boothroyd

Sea Level Rise



Carey

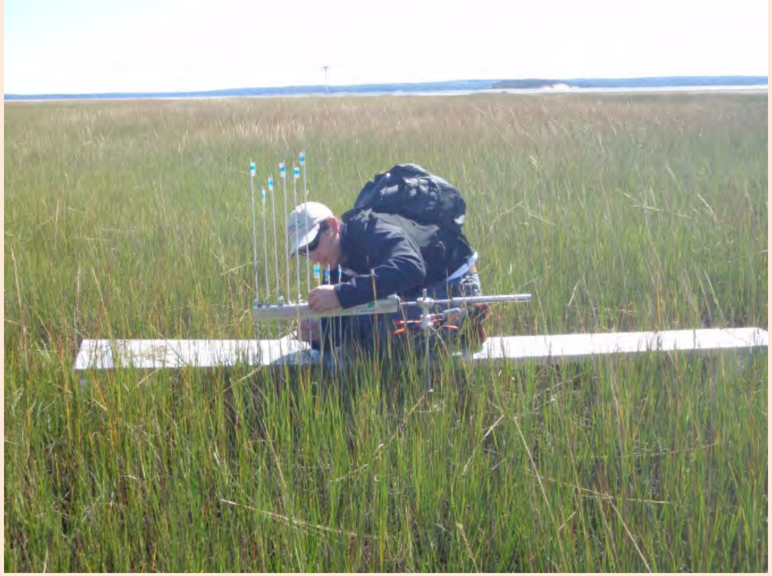
Marsh Accretion
Trends

Raposa RI Marsh Condition

Cole Ekberg Assessments

Warren
Trends in Long Island Sound

Starke
Elevation & Conservation



Carullo
MA CZM

Field
Tidal Marsh Birds

Ferguson
Strategies

Chafee
SLR :: CZM
? :: ??

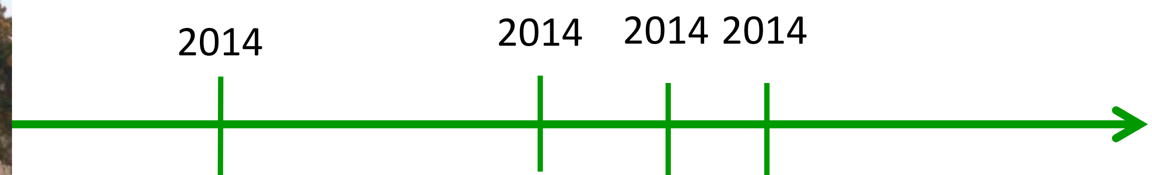
# Breakout Questions

- What management questions can researchers help address?
- What sm monitoring strategies are best?
- How best to prioritize sm restoration opportunities?

# Thank You

- All the participants who shared slides
- All my mentors, instructors and fellow marsh travelers


4-4518 Barrington, R.I. Rumstick Rd. from Point
AERIALS ONLY 508-295-5551 (c)
skypic.com


2014
2014
2014
2014

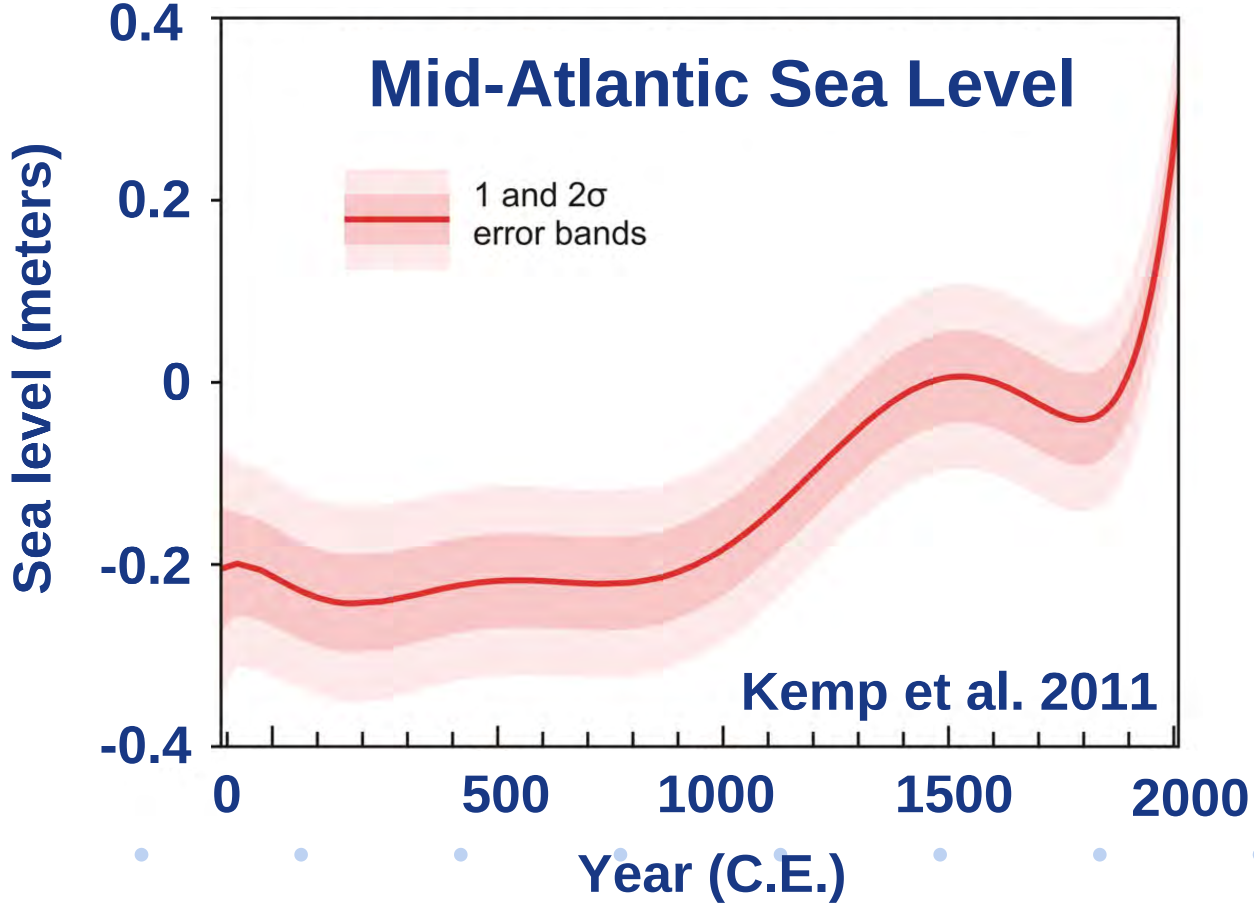
# Vulnerability of Rhode Island salt marshes to accelerated sea level rise

Elizabeth Burke Watson
Atlantic Ecology Division, U.S. EPA

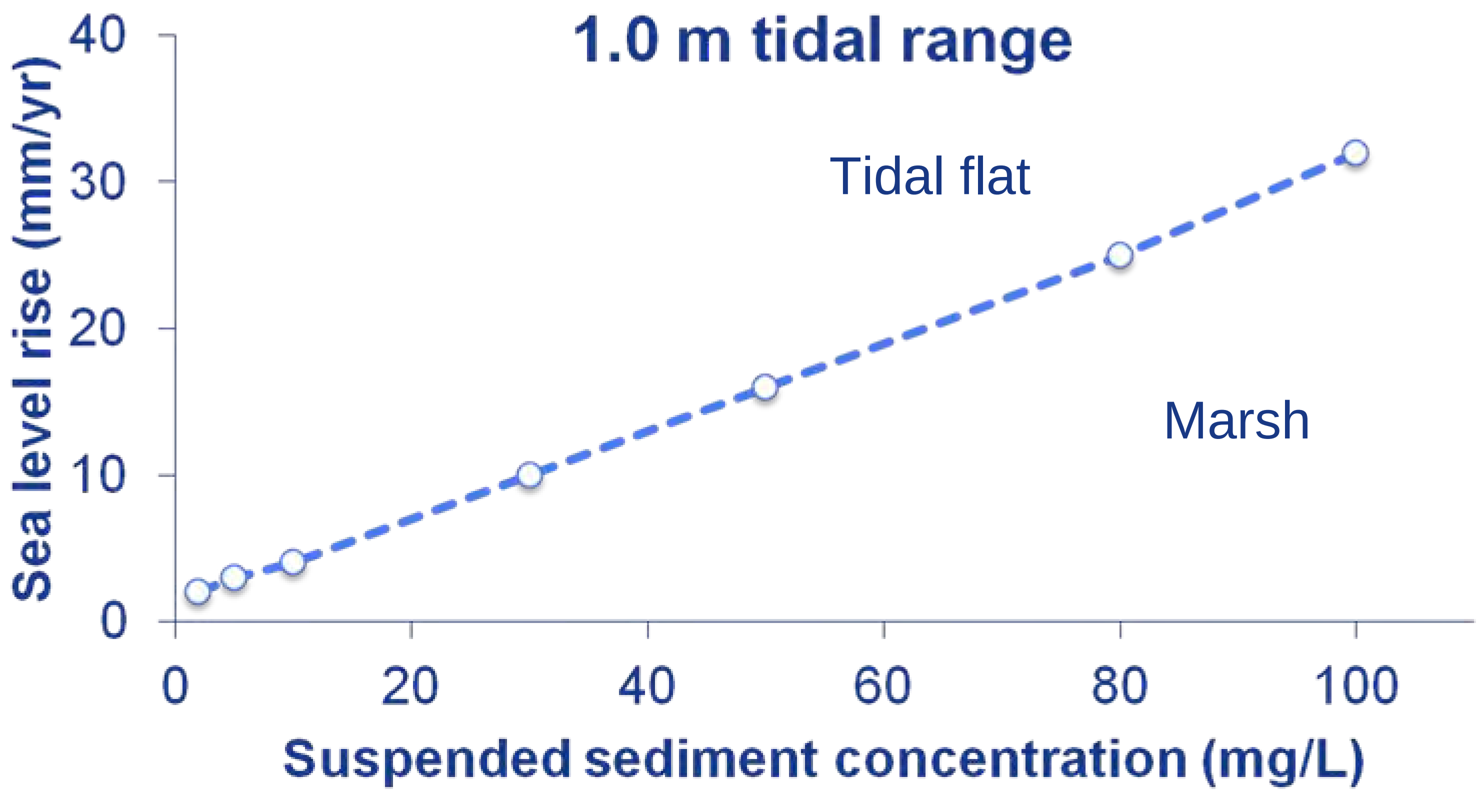
# Research Questions

- Are Rhode Island salt marshes disappearing?
- What role is sea level rise playing in marsh loss?
- Will high nutrient loads exacerbate marsh loss?

# Accelerated sea level rise

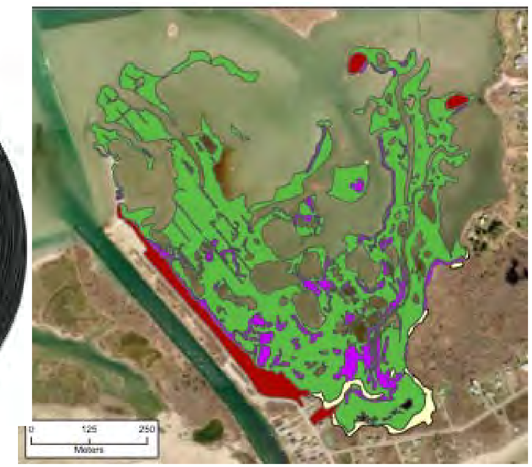


# Threshold sea level rise rates

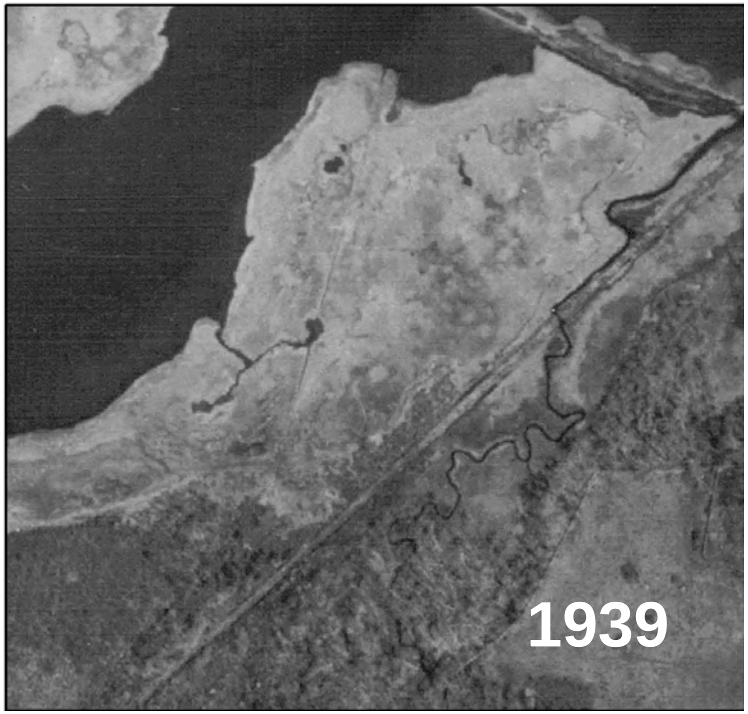



Kirwan et al. 2010; Fagherazzi et al. 2012

# Data collection



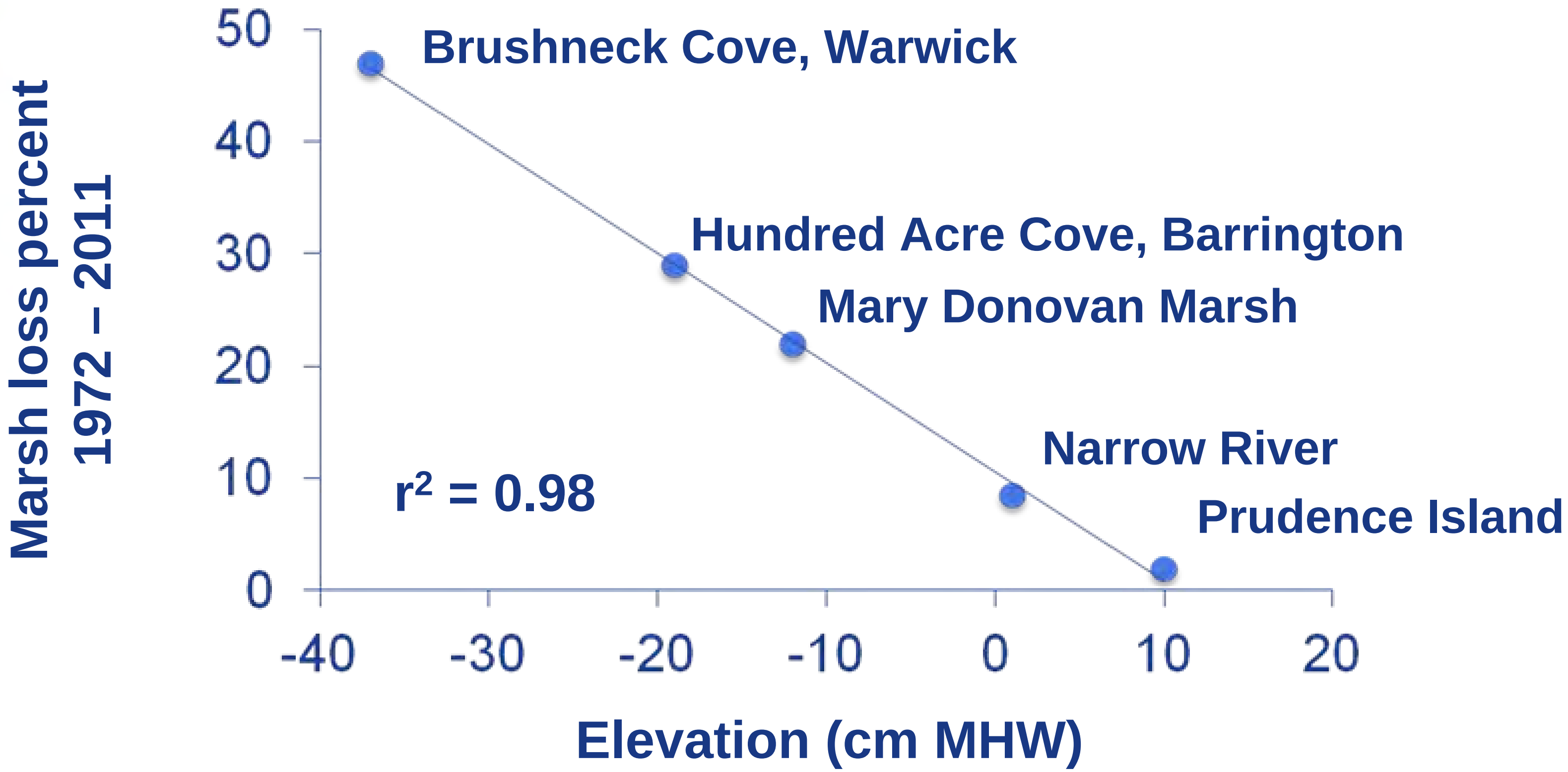

# Narragansett, RI marsh ponding




# Barrington, RI marsh loss

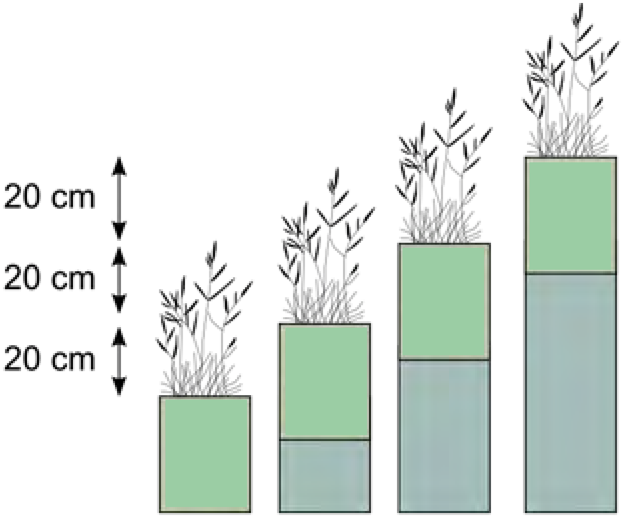

# Bristol, RI tidal channel expansion


# Marsh loss as a function of elevation



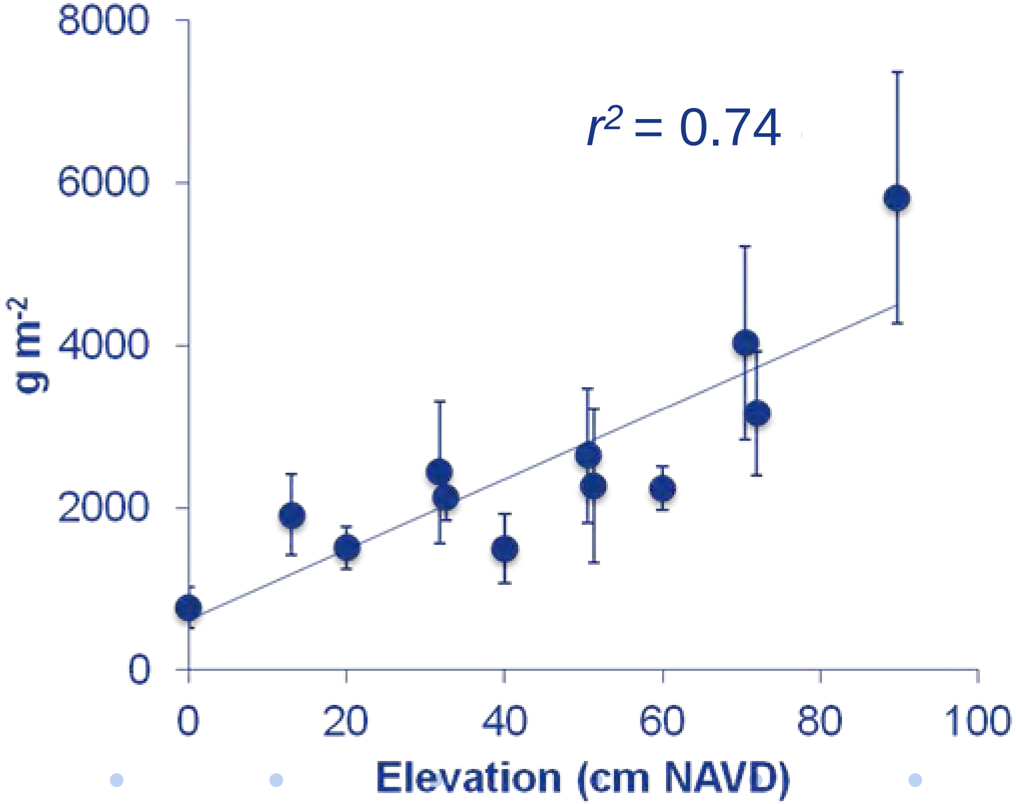
# Mesocosm research

Marsh 'organ' experiments

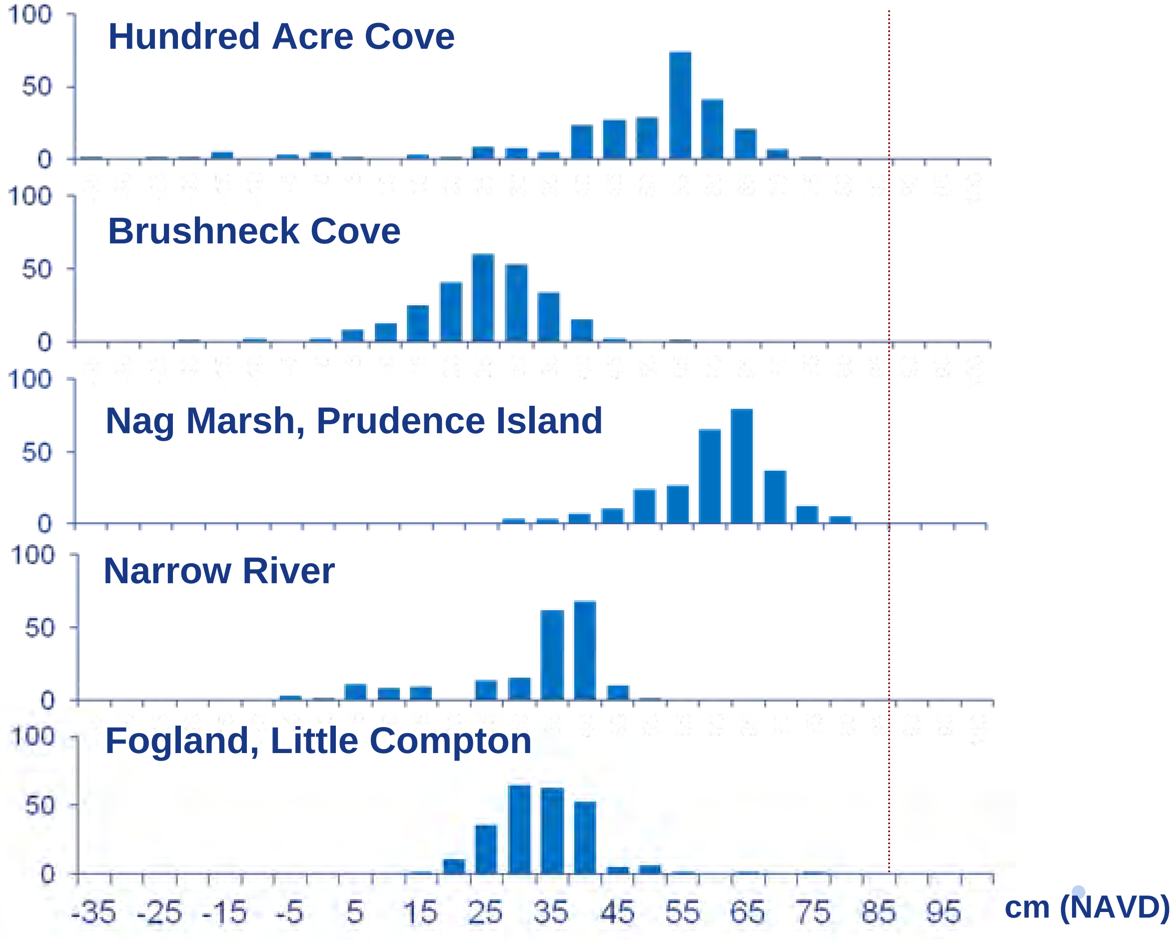



# Productivity responds to elevation

*Spartina alterniflora* elevation-productivity relationship



# Elevation distribution for 5 RI salt marshes



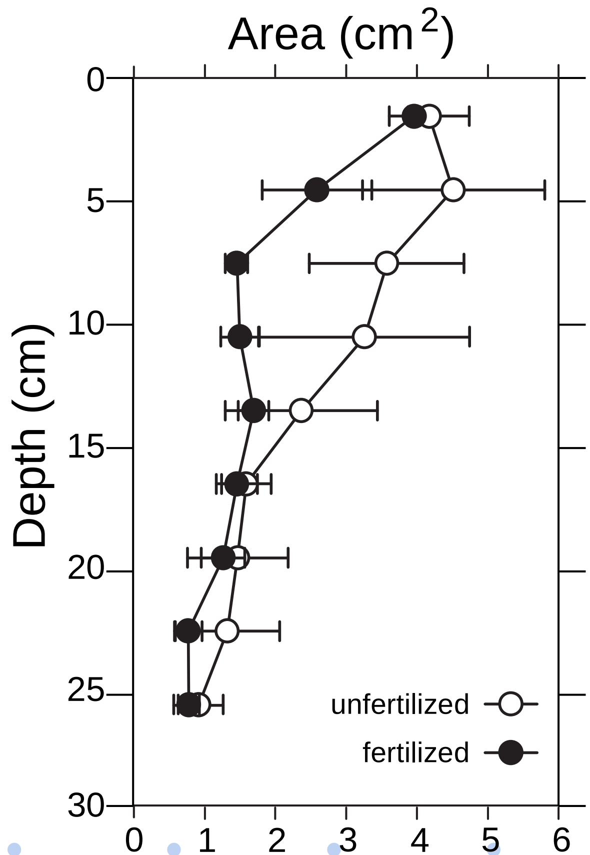
# Laboratory mesocosm research

# Water column nutrient additions

- Elevated porewater $H_2S$ (by +84%)
- More rapid decomposition
  - 28% higher litter mineralization
  - 67% higher bare soil $CO_2$ efflux
- Decrease in coarse roots & rhizomes

# Coarse roots and rhizomes

Unfertilized




Fertilized

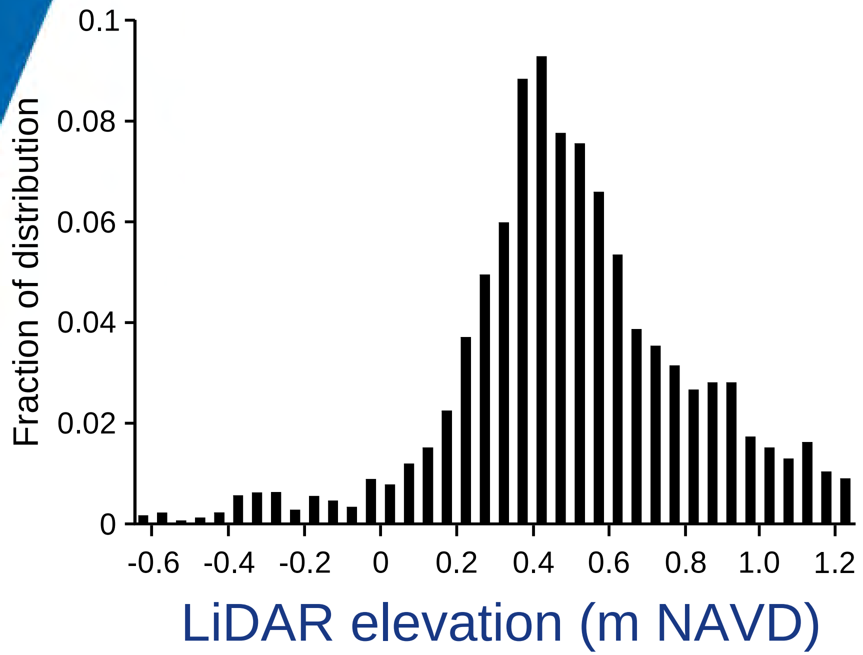
# Conclusions

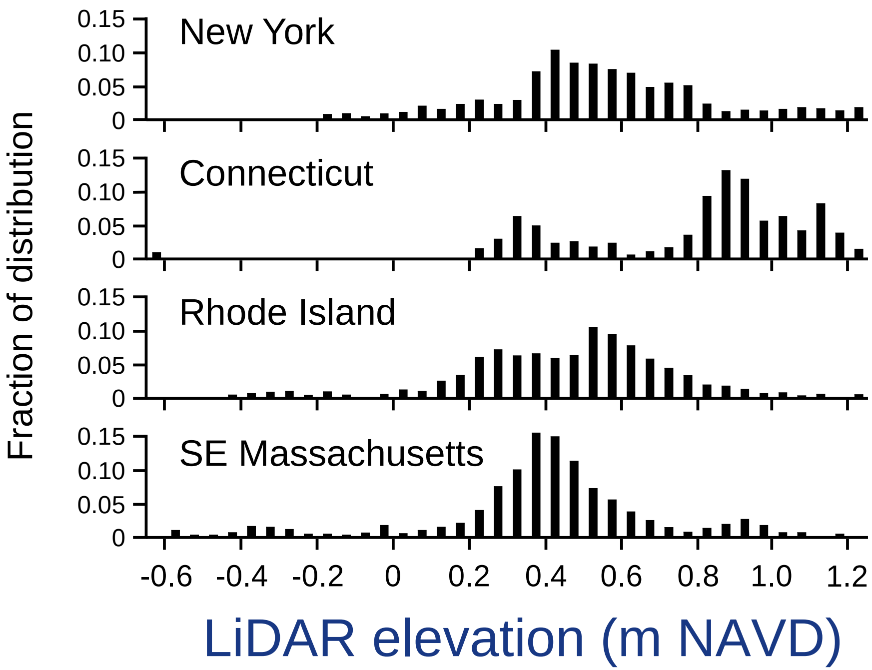
- Marsh fragmentation is occurring
- Marsh loss linked with low elevations
- Productivity is limited by current inundation patterns

# Acknowledgements

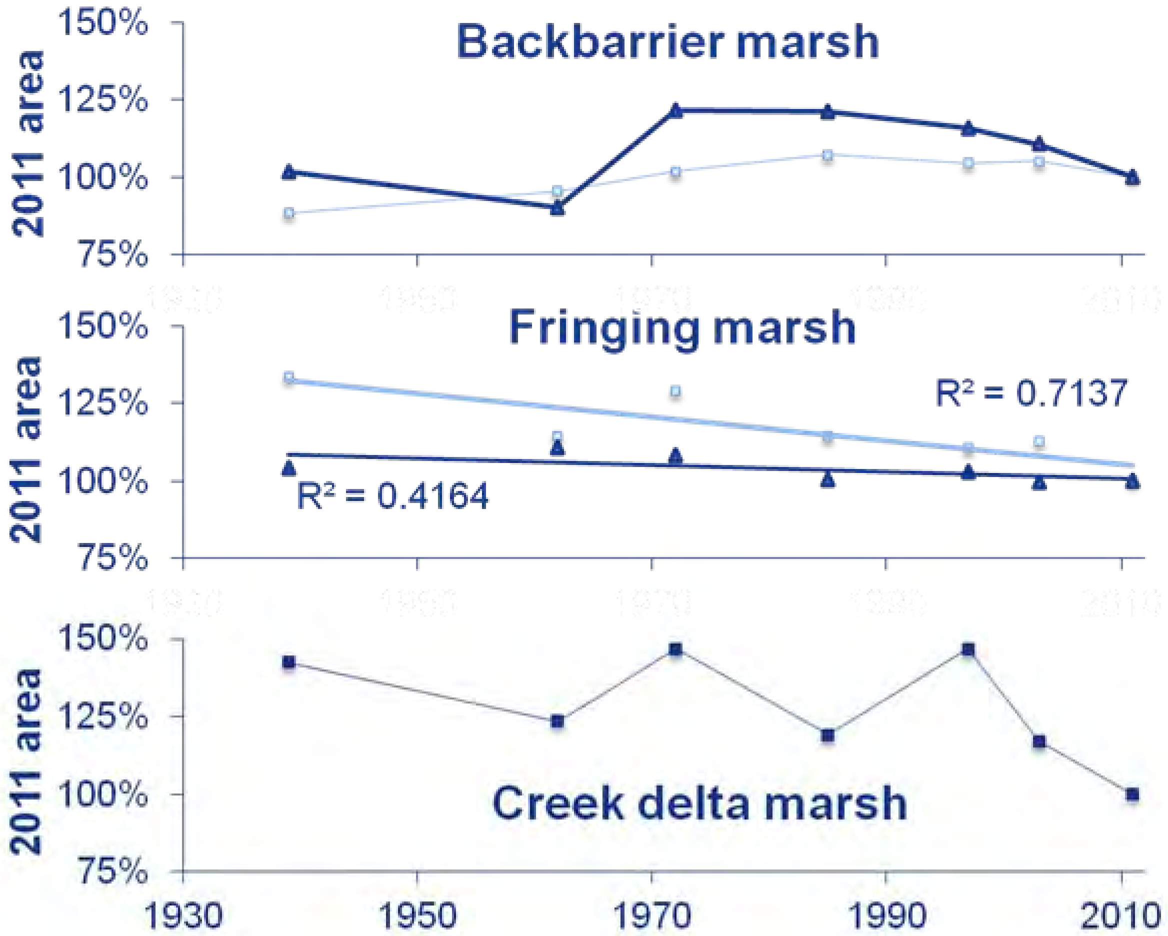

- US EPA: **Cathy Wigand, Autumn Oczkowski, Alana Hanson, Earl Davey, Roxanne Johnson**, Giancarlo Cincchetti, Marty Chintala
- Brown University: **Sarah Crosby**
- NBNERR: Kenny Raposa, Jen West
- RICRMC: Caitlin Chaffee
- Save the Bay: Marci Cole Eckberg, Wenley Ferguson

# Elevation distribution for 38 NE salt marshes



# Trends in marsh loss for RI



# Rationale

# Trends in marsh loss for RI

- For backbarrier marshes: 12.0% loss since 1985
  - *But* a 5.7% gain since 1939
- For fringing marshes: 4.9% loss since 1985
  - *But* a 33.5% loss since 1939
- Sums to a 9.8% loss since 1985

Berry *et al.*, in prep

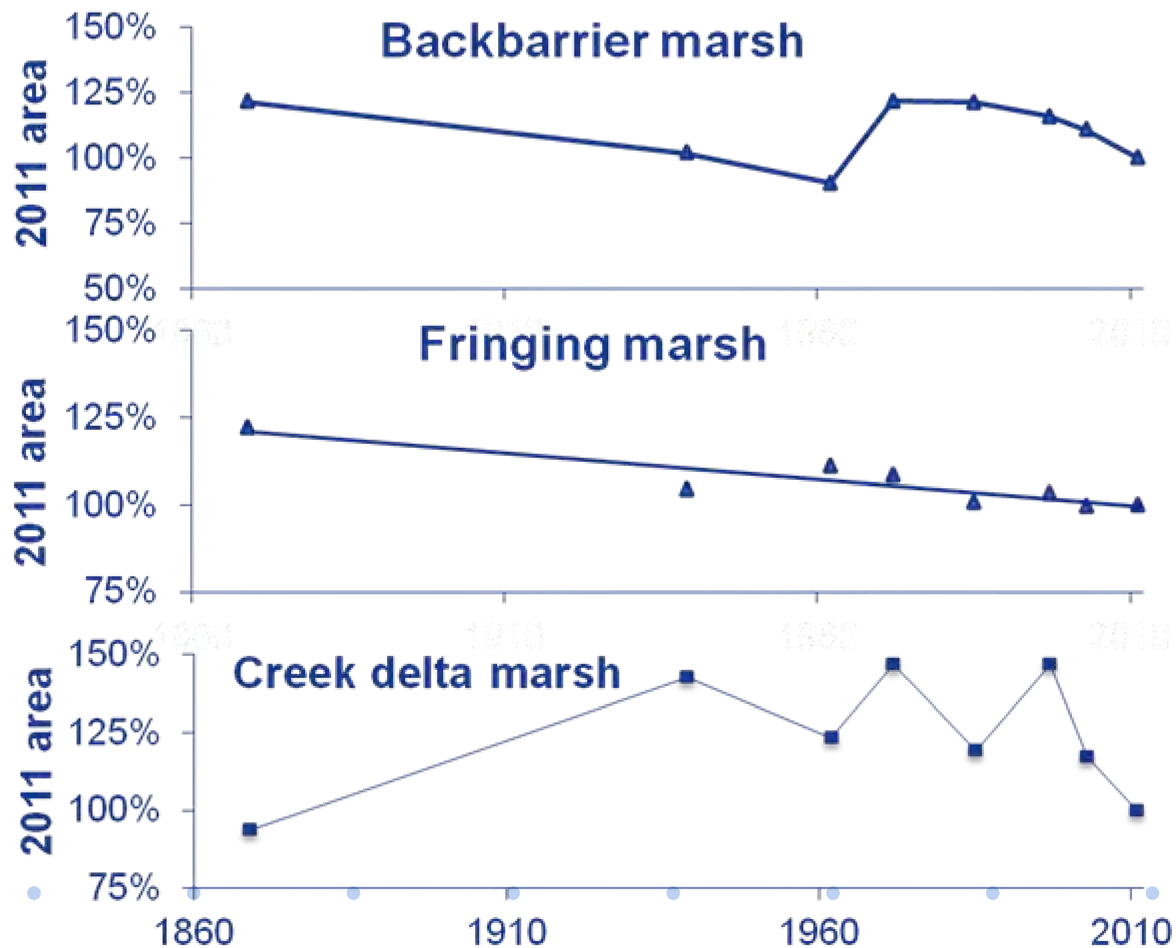
| | |
|---|---|
| 1981 | 534.2 ha |
| 2008 | 477.5 ha |

8.9% loss

Halvorsen & Gardiner 1976

| | |
|---|---|
| 1955-1964 | 5.3% loss |
| 1962-1975 | 23.5% loss |

# Trends in marsh loss for RI



# Marsh elevation modeling

- Sediment settlement models
  - Krone 1987; French 1996; Temmerman et al. 2006
- Cohort models
  - Callaway 1996; Morris et al. 2002
- Landscape models
  - SLAMM
- Hydrodynamic models
  - DELft3D

# Marsh elevation modeling

$$\Delta z = \frac{\int^{t} V_s C}{C_d}$$

**Rising tides**

$$\frac{d\eta}{dt} \geq 0 \quad (\eta - z)\frac{dC}{dt} = -V_s C + (C_o - C)\frac{d\eta}{dt}$$

**Falling tides**

$$\frac{d\eta}{dt} \leq 0 \quad (\eta - z)\frac{dC}{dt} = -V_s C$$

$V_s = KC^{\frac{4}{3}}$
$C_d = lithic\ sediment\ density$
$\eta = water\ level$
$C = suspended\ sediment\ concentration$
$C_o = ambient\ ssc$
$V_s = settling\ velocity$
$t = time$
$z = marsh\ elevation$

**Krone 1987**

# Climate Adaptation Strategies

- Monitoring / tiered assessment strategy
- Plan for salt marsh migration opportunities
- Pilot experiments in thin layer dispersal, drainage enhancements, and shoreline protection

**Salt marsh sea level rise workshop on April 16, 2014 at Save the Bay in Providence, RI**

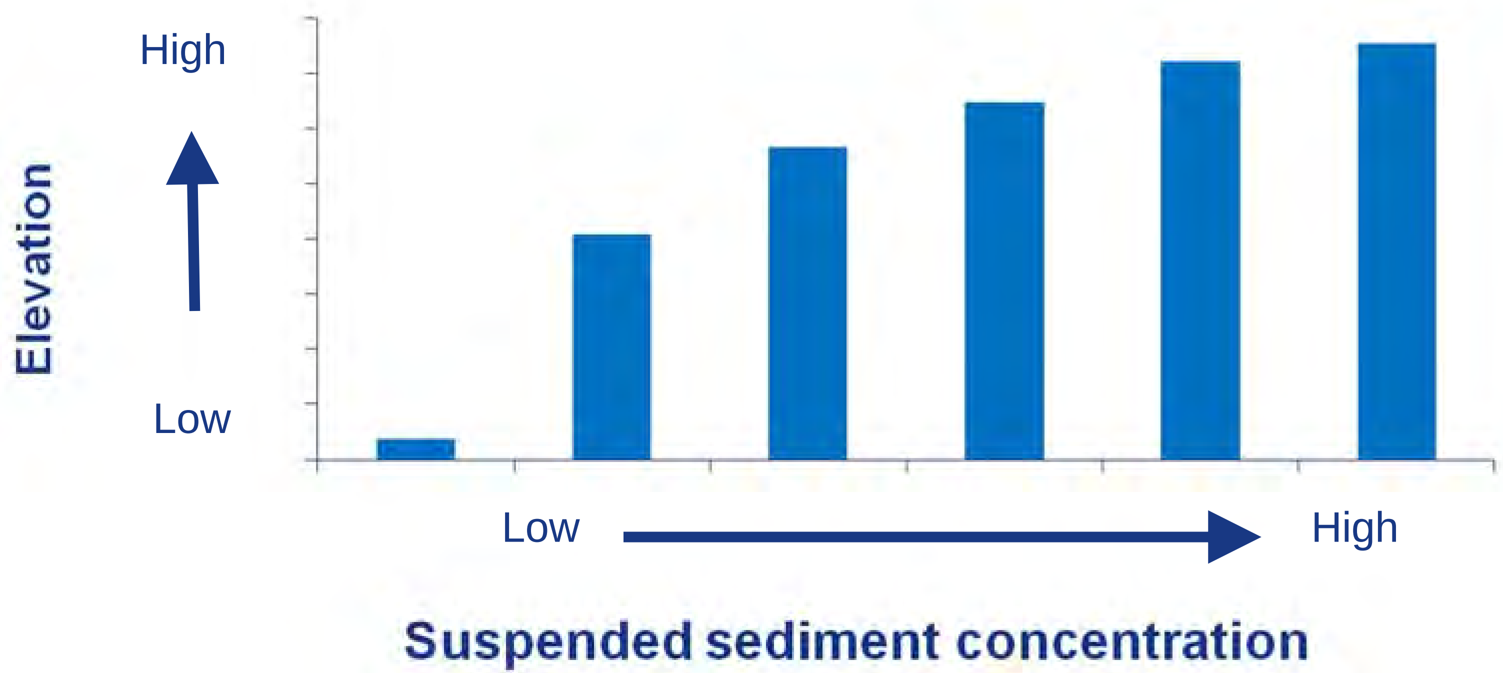
# Model Inputs

- Sediment composition
- Water levels from 2011
- Sea level rise rate of 1 mm $y^{-1}$ (Donnelly et al. 2004)
- Varied suspended sediment concentration

Allowed model to run to equilibrium

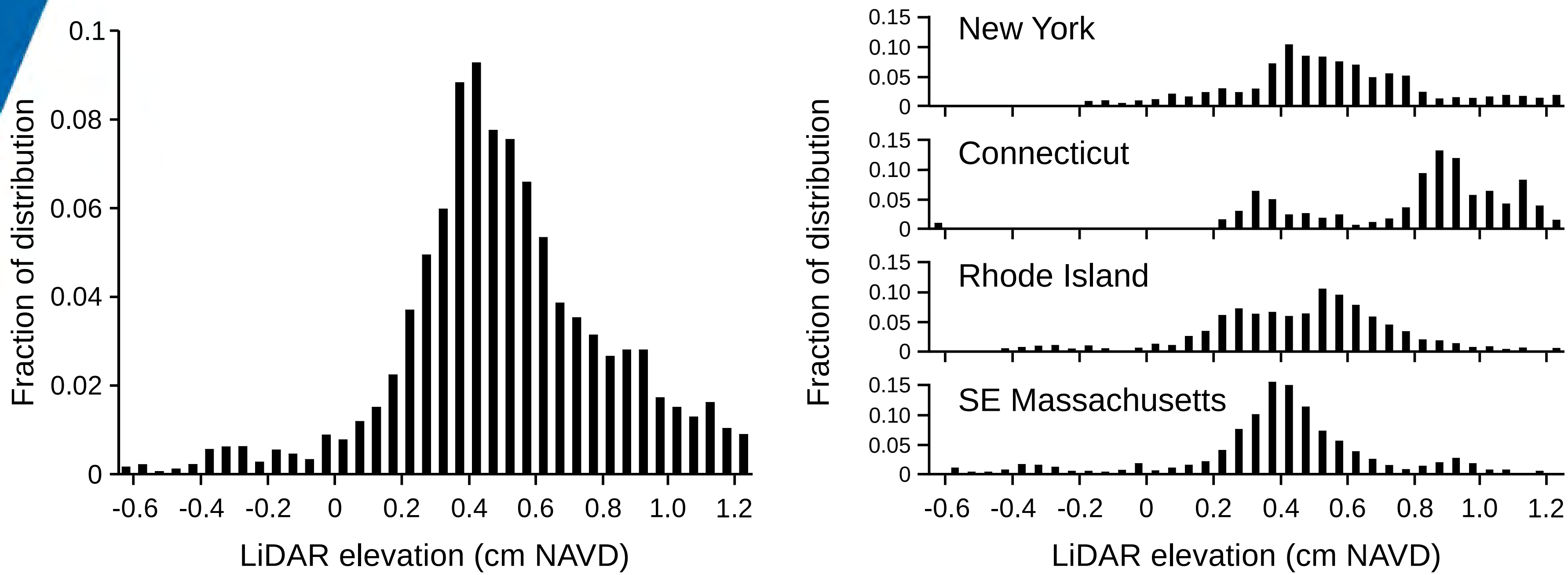
# Marsh elevation modeling

**Equilibrium marsh elevations as a function of suspended sediment concentration**



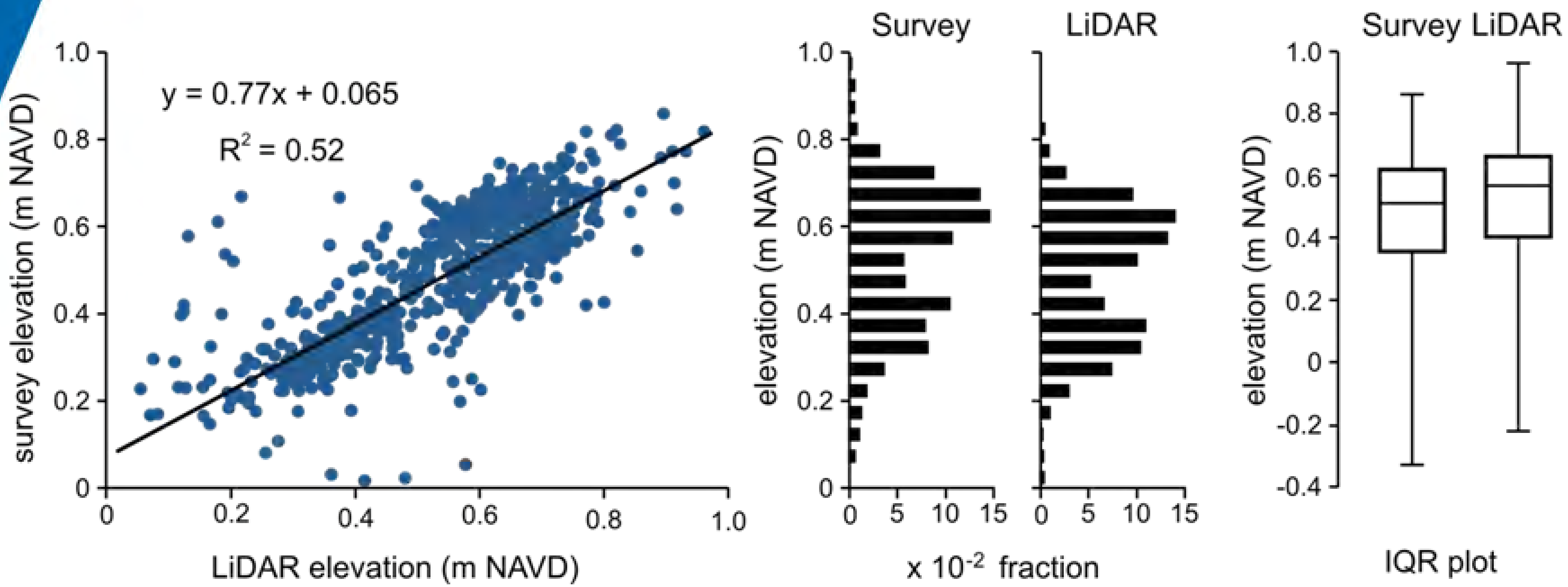
# Elevation capital assessment

Distribution of salt marsh elevations for 38 Northeastern salt marshes

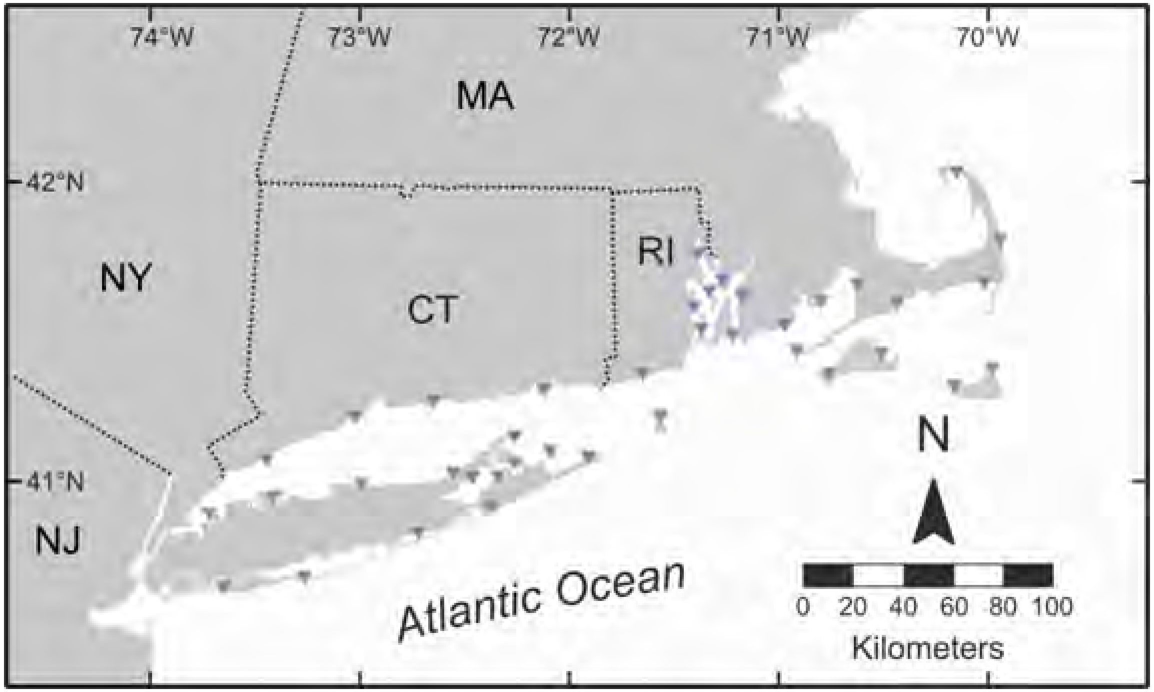


# Elevation capital assessment

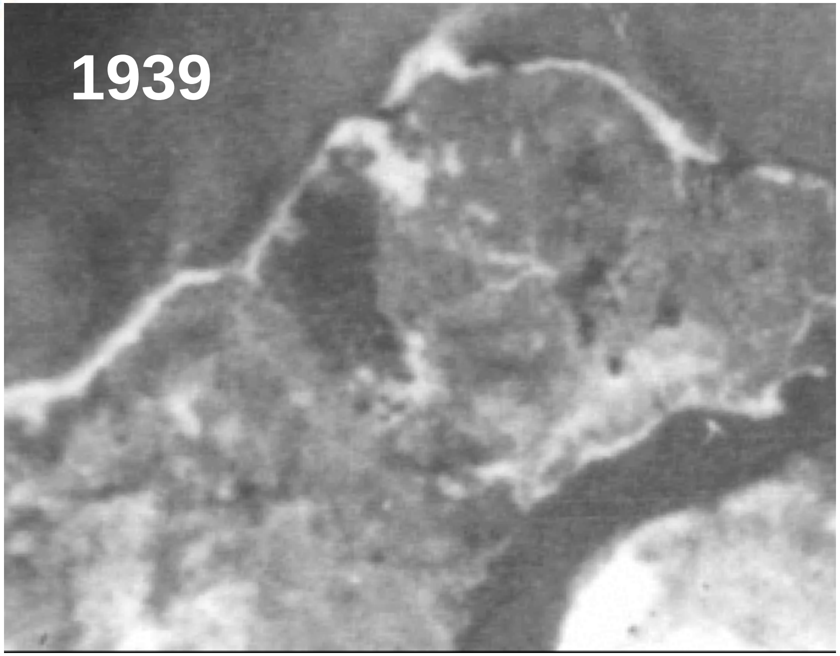
Comparison of survey with LiDAR elevations



# Elevation capital assessment

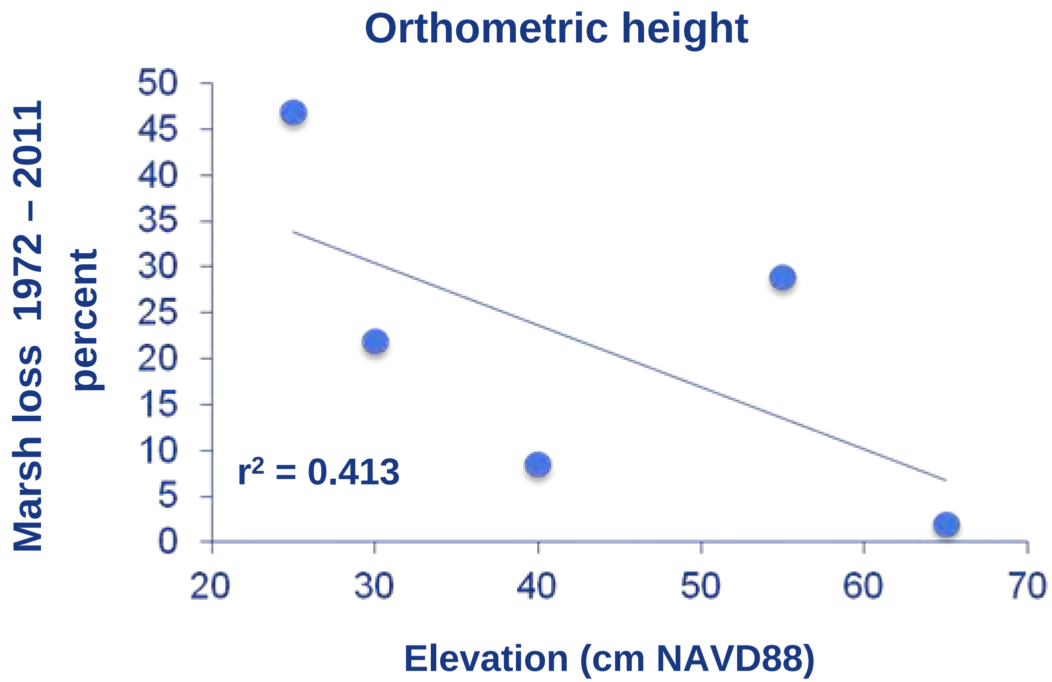


# Winnapaug Pond, RI




# Marsh loss patterns

Marsh loss as a function of elevation



# LATE HOLOCENE and ANTHROPOCENE SEA-LEVEL RISE: PAST, PRESENT and FUTURE for RHODE ISLAND

*The Effects of Sea-Level Rise on RI's Salt Marshes*
*Save The Bay*

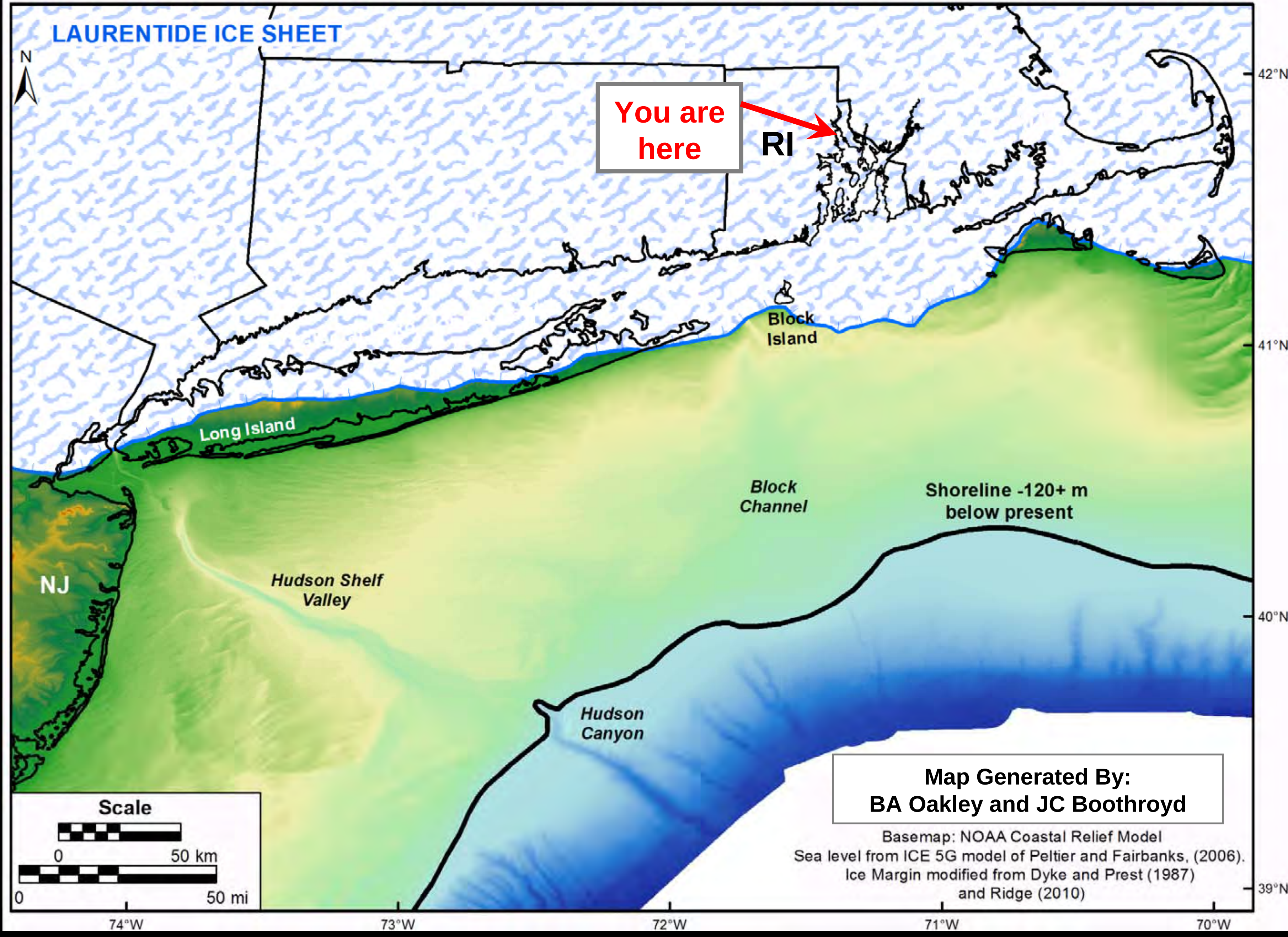
*16 April 2014*

*Jon C. Boothroyd[1,2] and Bryan A. Oakley[1,3]*

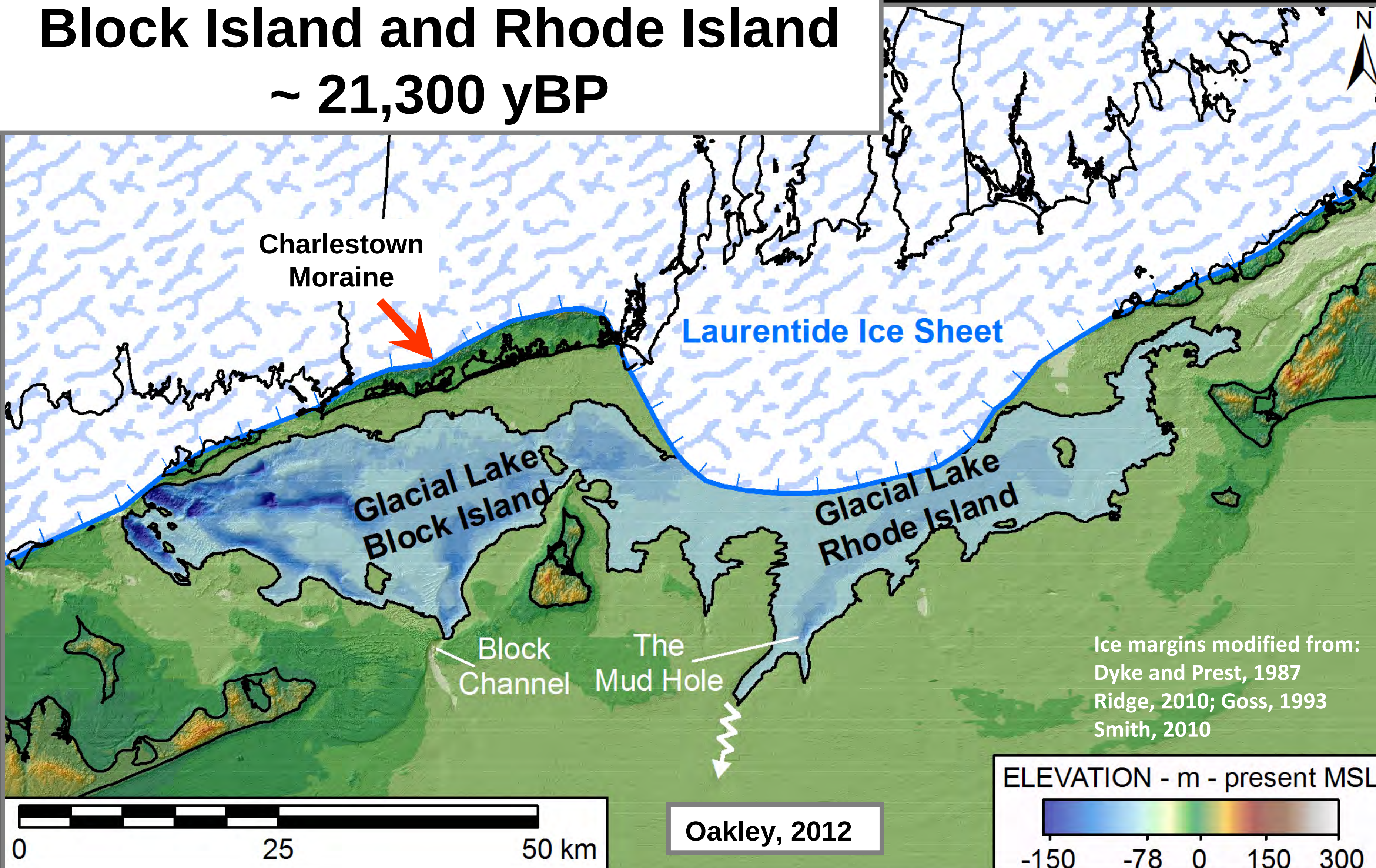
(1) Rhode Island Geological Survey
(2) Department of Geosciences, University of Rhode Island, Kingston RI 02881
(3) Environmental Earth Science Department, Eastern Connecticut State University, Willimantic, CT 06226

# First,
# Some Geological Background Information
# ---------
# Glacial Geology and Climate

# S New England, E New York, Continental Shelf at LGM ~ 26,000 yBP



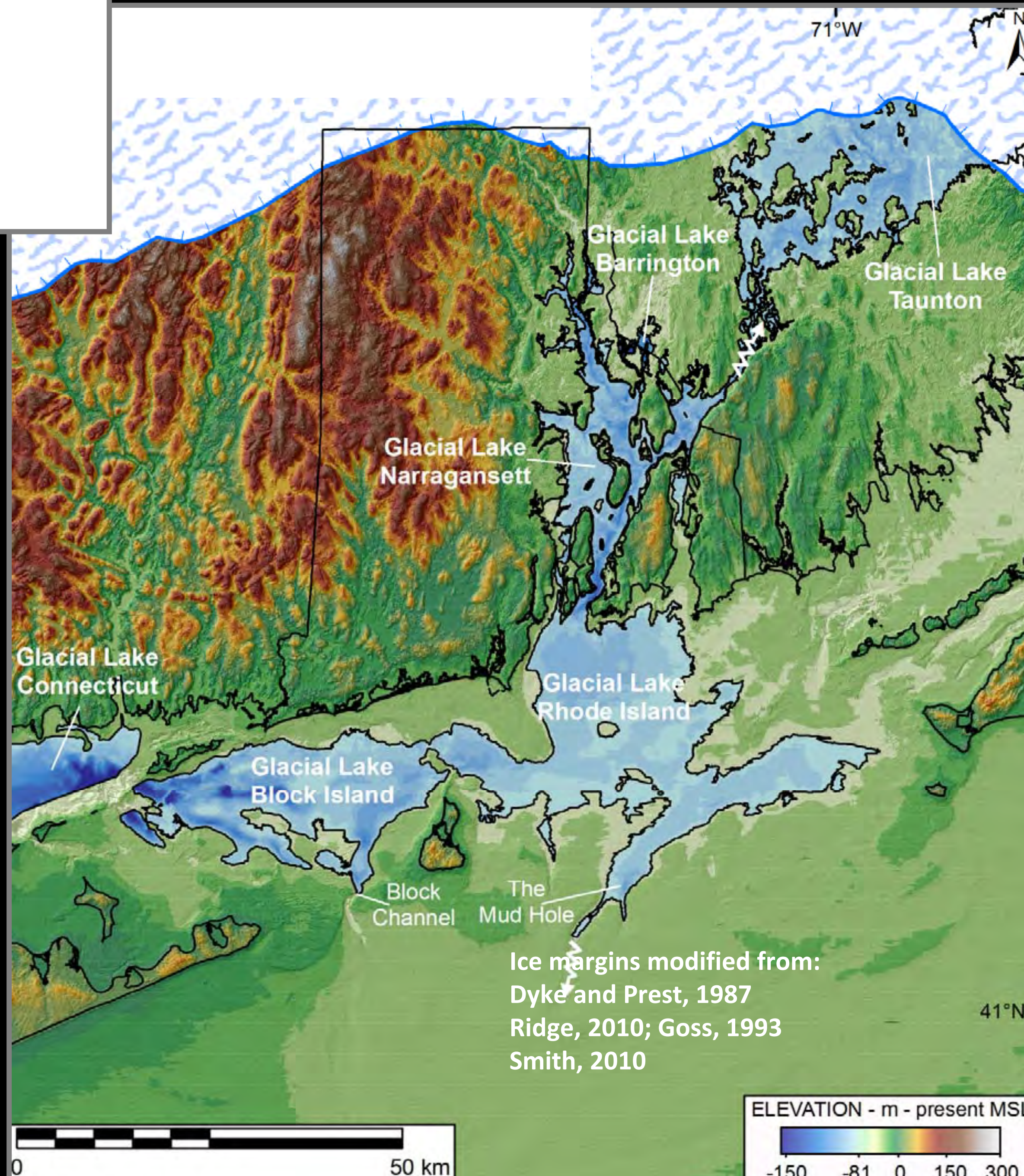
# Glacial Lakes
# Block Island and Rhode Island
# ~ 21,300 yBP

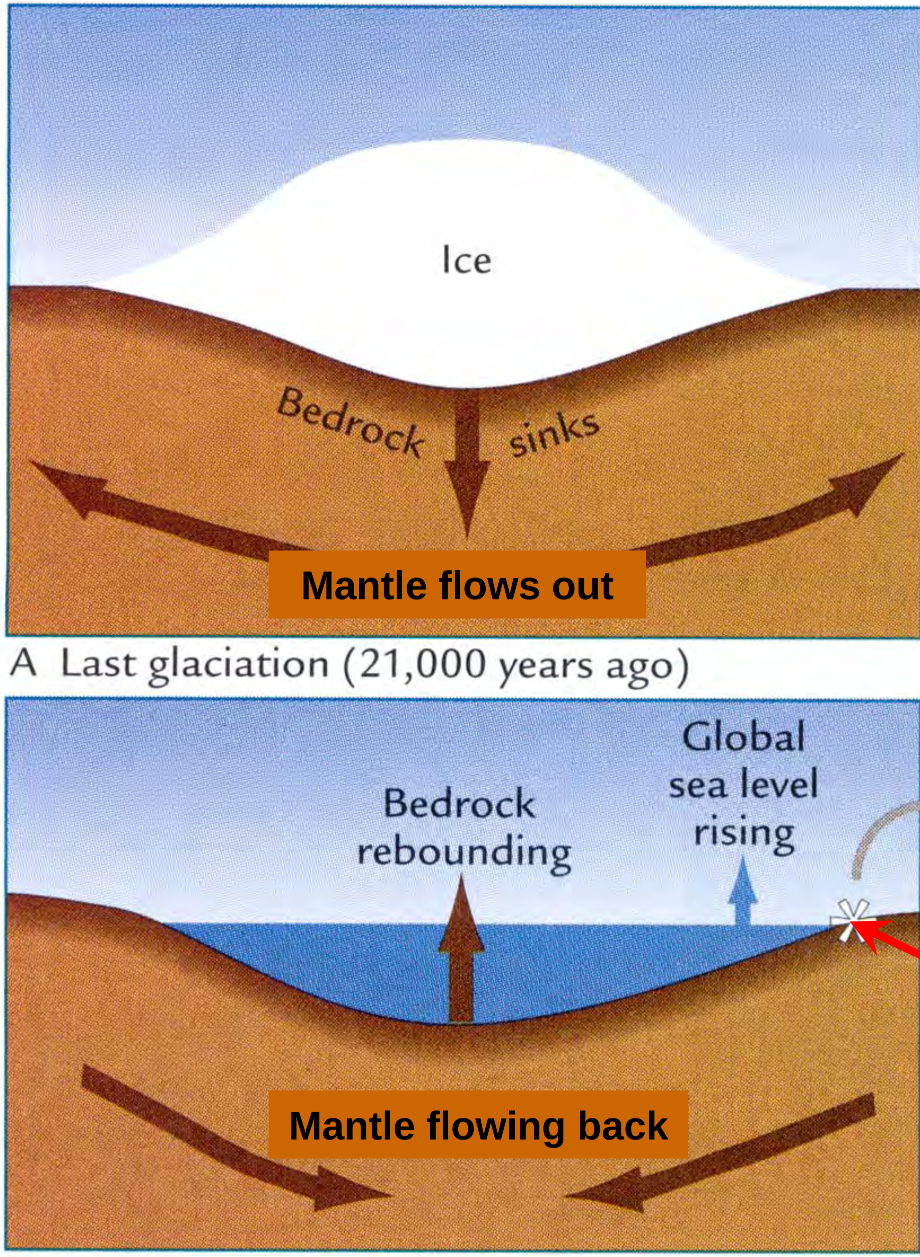


# Glacial Lake Narragansett ~ 18,500 yBP

Oakley, 2012

## Laurentide Ice Retreat From RI





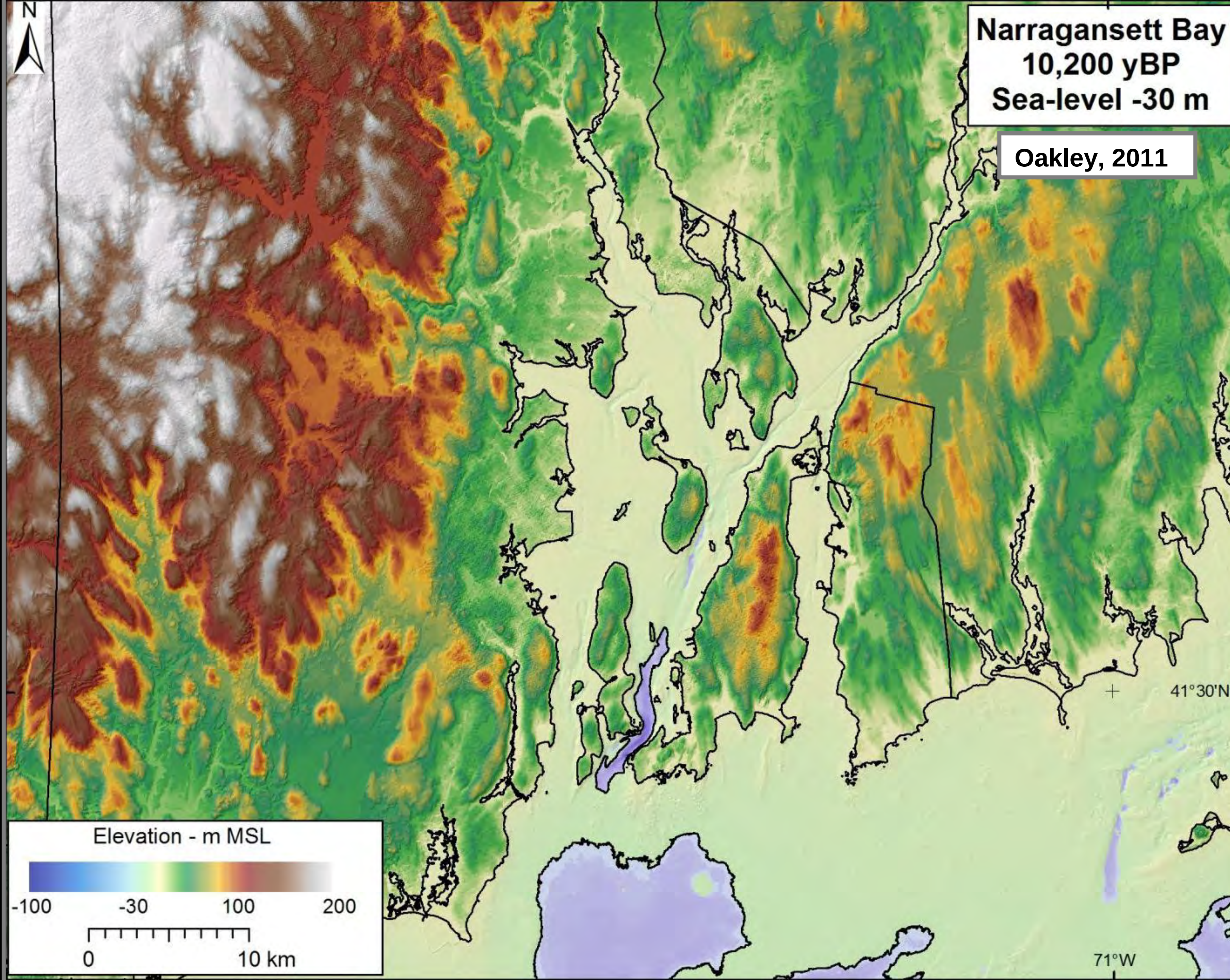
A Last glaciation (21,000 years ago)
B Today

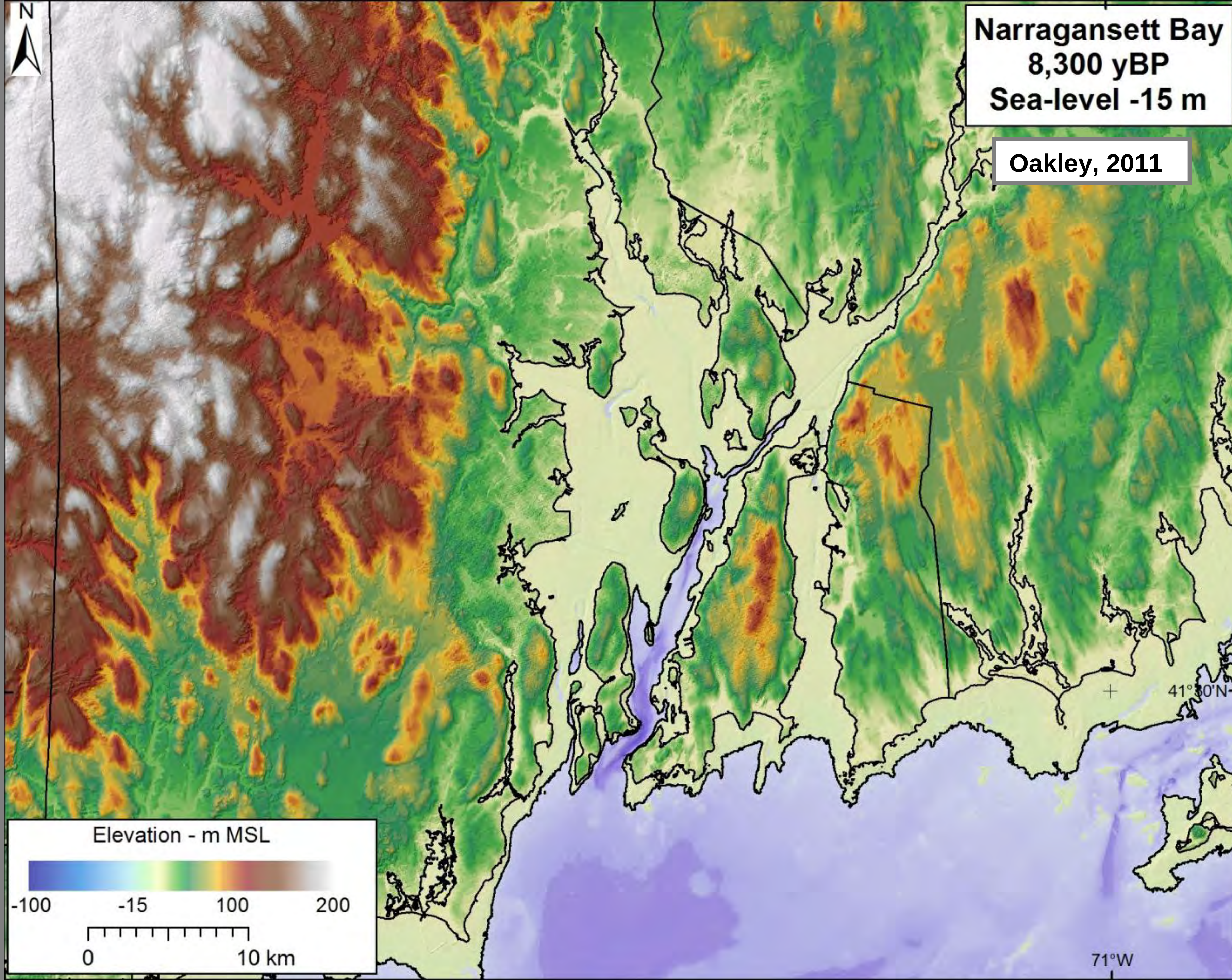
Isostatic Depression

Isostatic Rebound

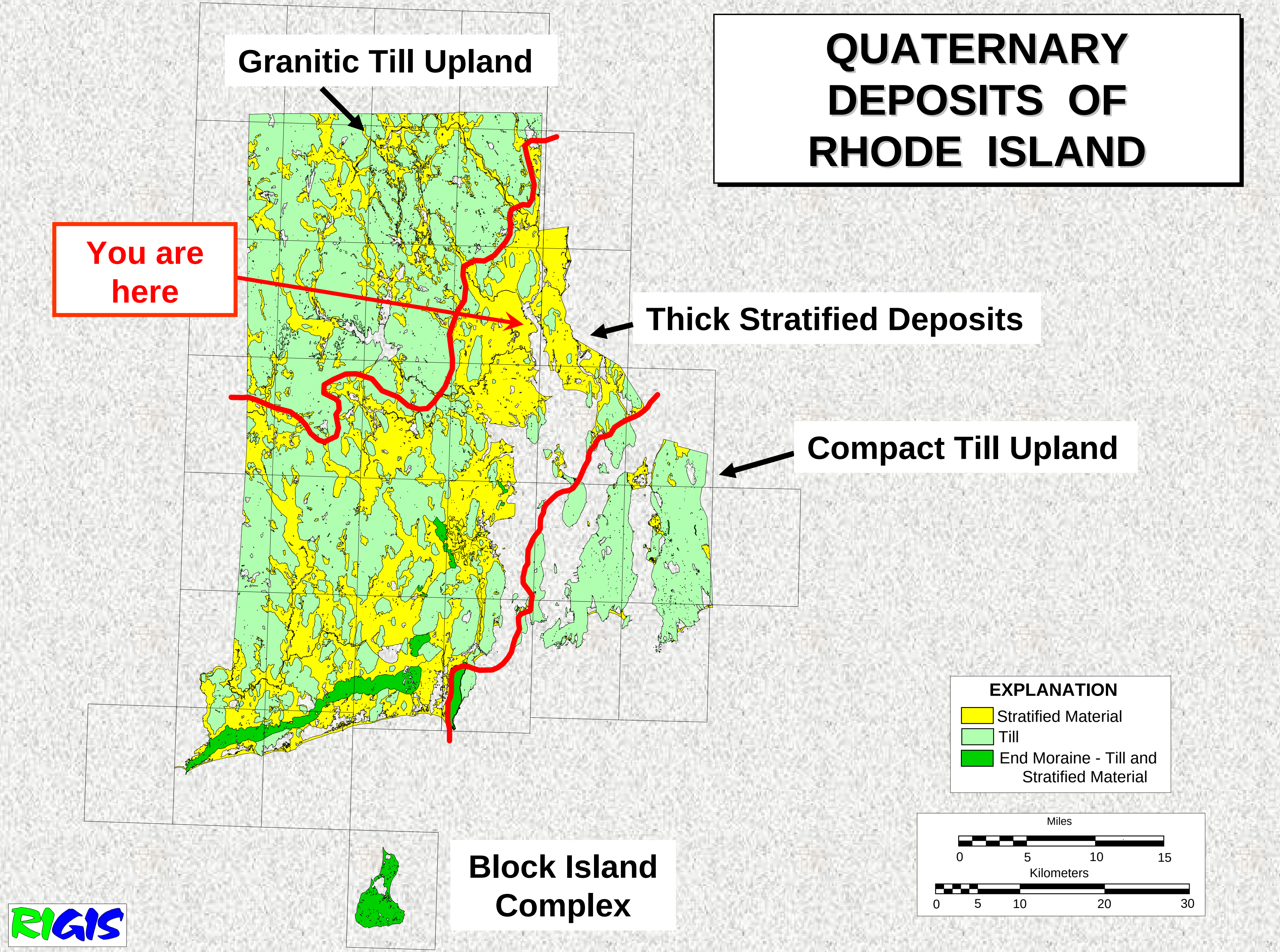
Rhode Island

W F Ruddiman, 2001

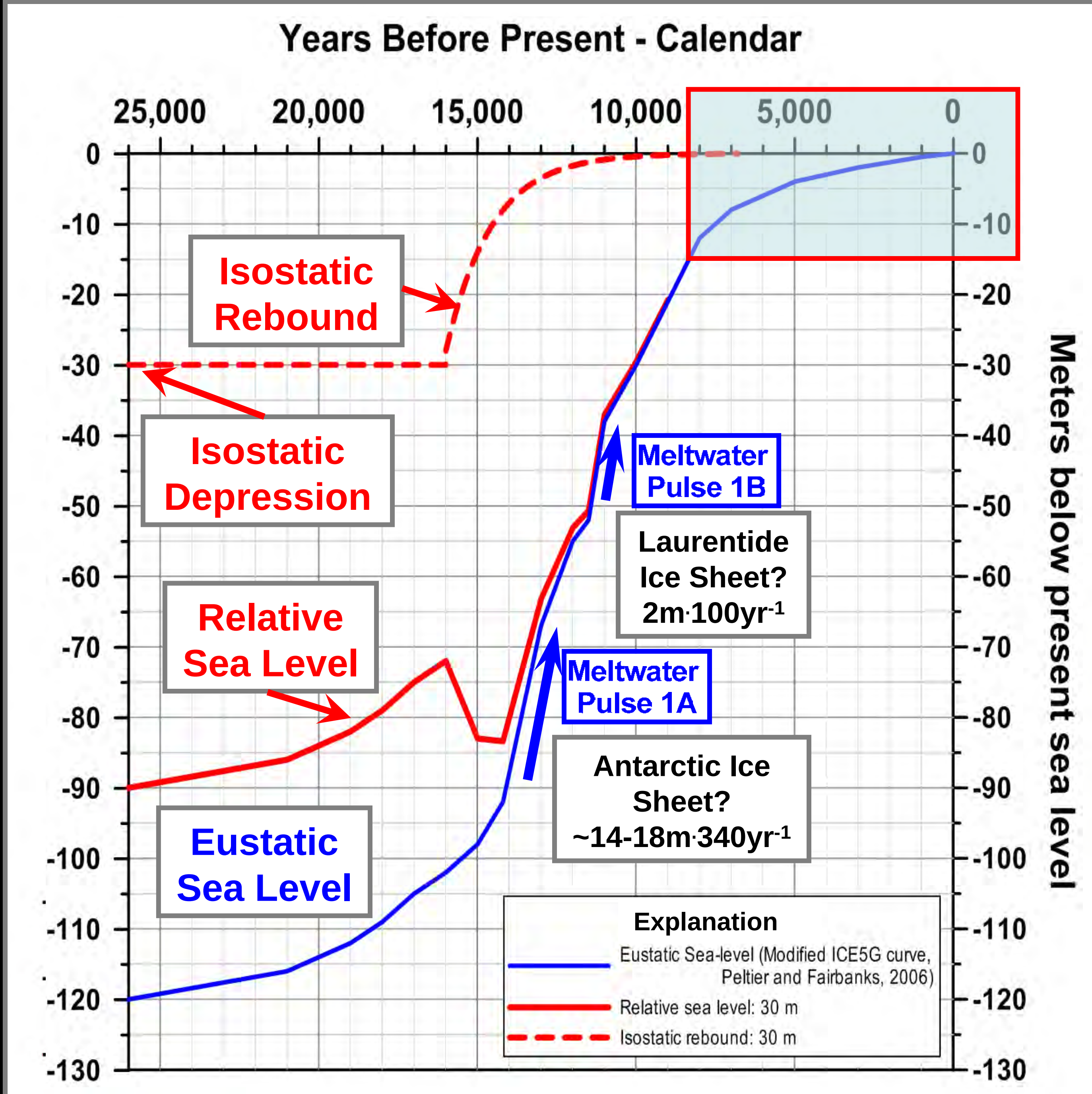

Narragansett Bay
10,200 yBP
Sea-level -30 m
Oakley, 2011
N
Elevation - m MSL
-100
-30
100
200
0
10 km
41°30'N
71°W


Narragansett Bay
8,300 yBP
Sea-level -15 m
Oakley, 2011
N
Elevation - m MSL
-100
-15
100
200
0
10 km
41°30'N
71°W

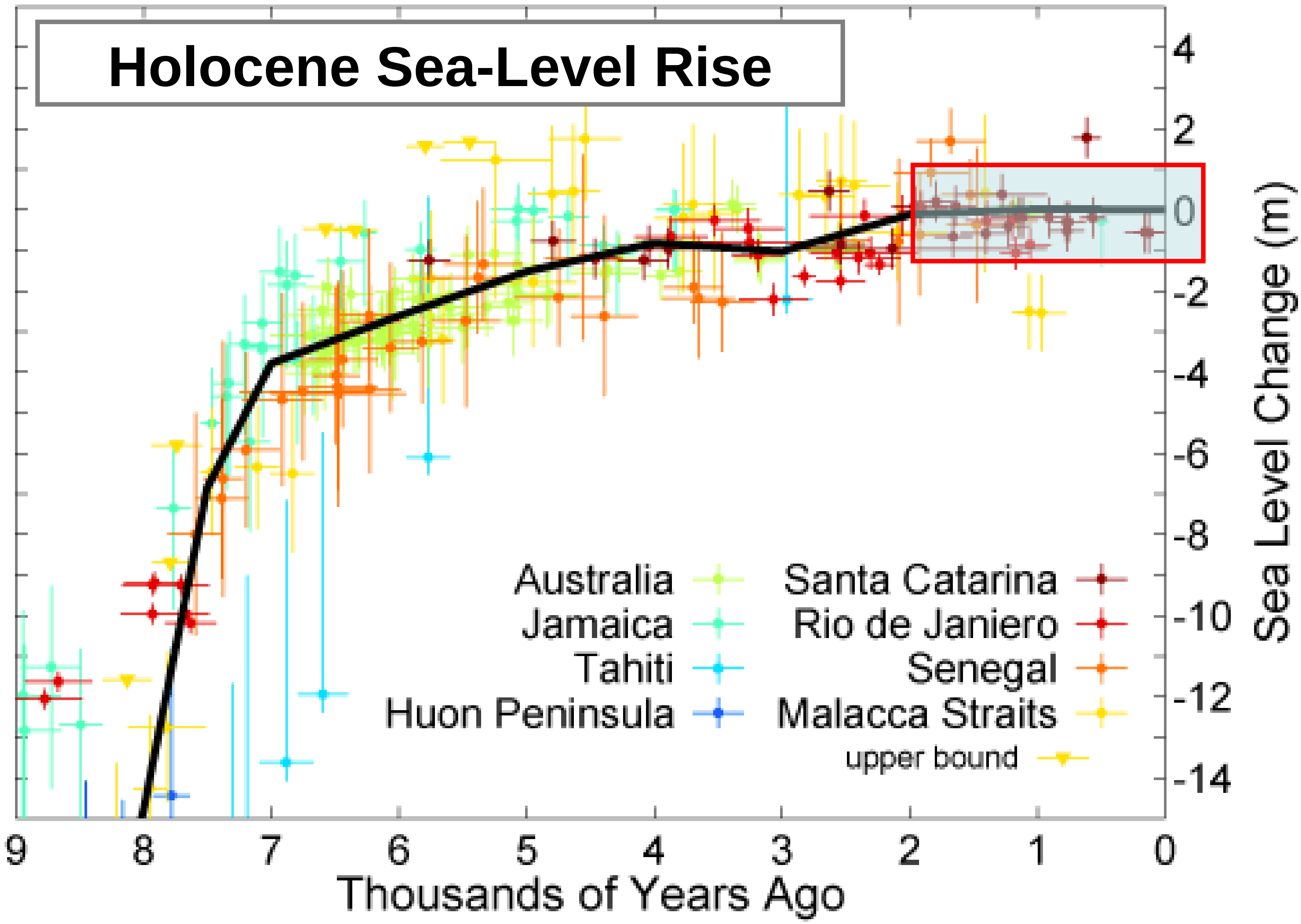
# QUATERNARY DEPOSITS OF RHODE ISLAND



# Eustatic Sea-Level Rise + Isostatic Rebound at Block Island RI

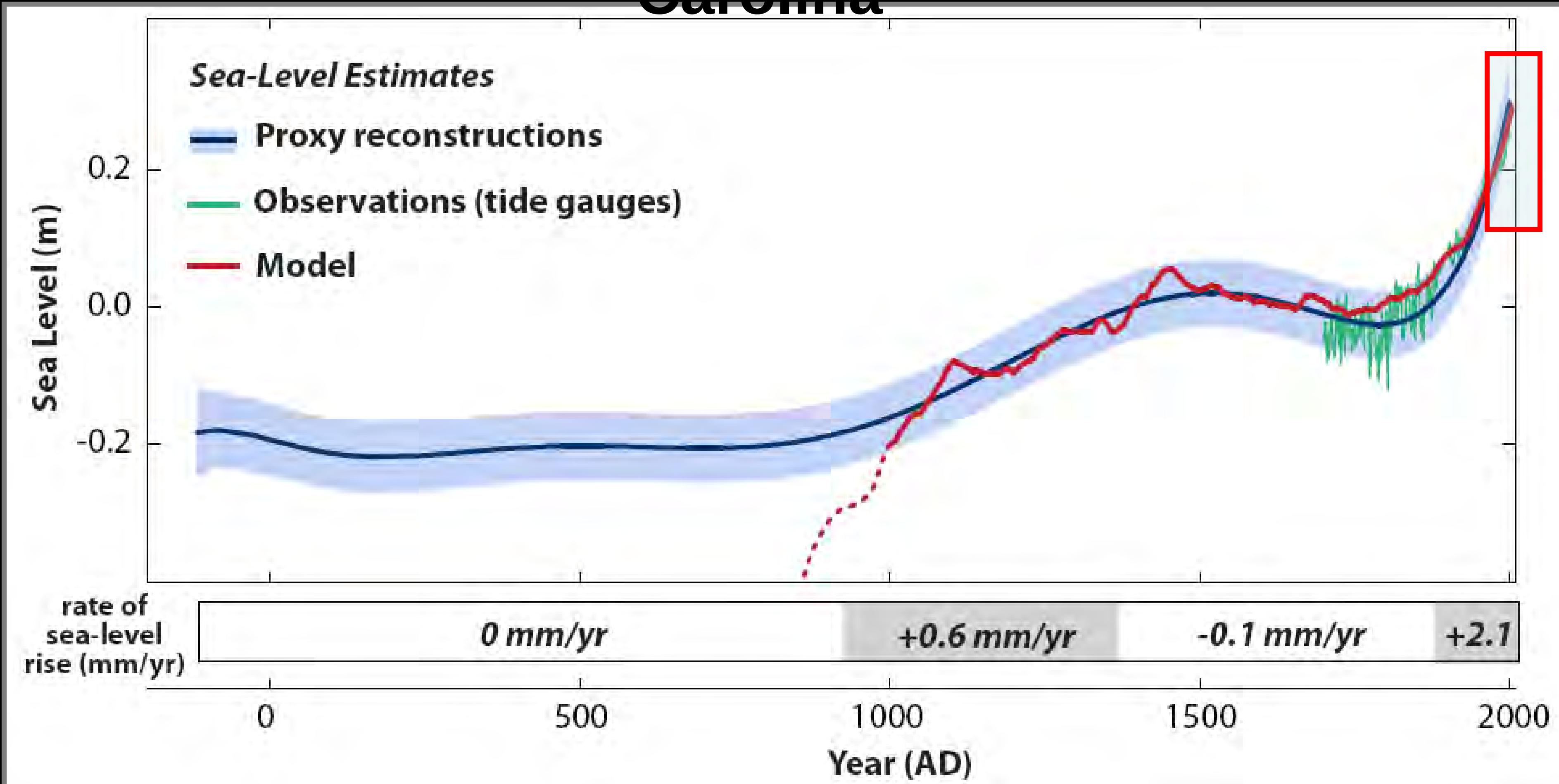



Adapted from: Oakley and Boothroyd, July 2012

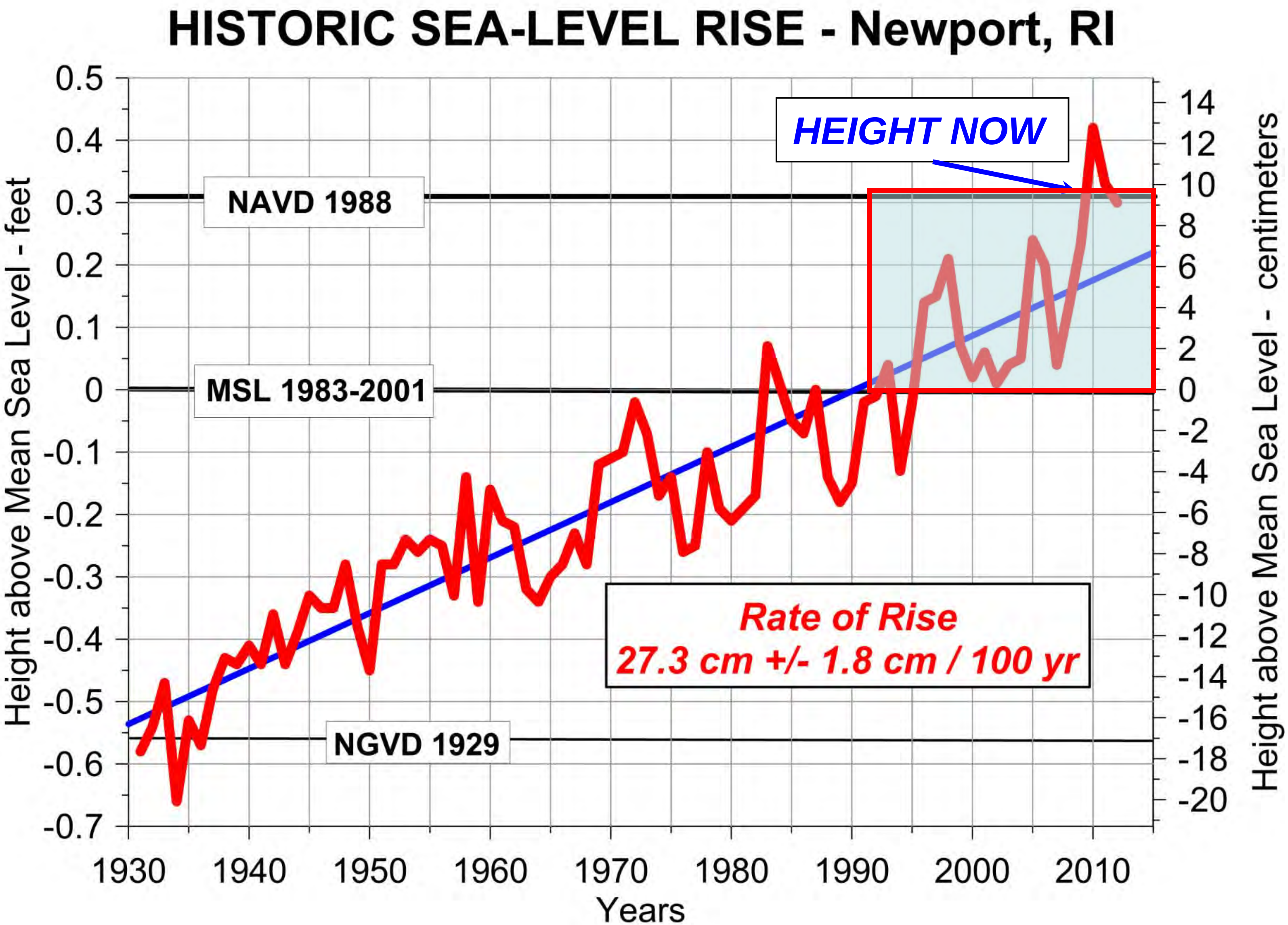



GlobalWarmingArt.Com from: Fleming et al. 1998, Fleming 2000, & Milne et al. 2005

# Sea-Level Rise Past 2000 Years – North Carolina




Kemp, Horton, Donnelly, Mann, Vermeer and Rahmstorf 2011 PNAS



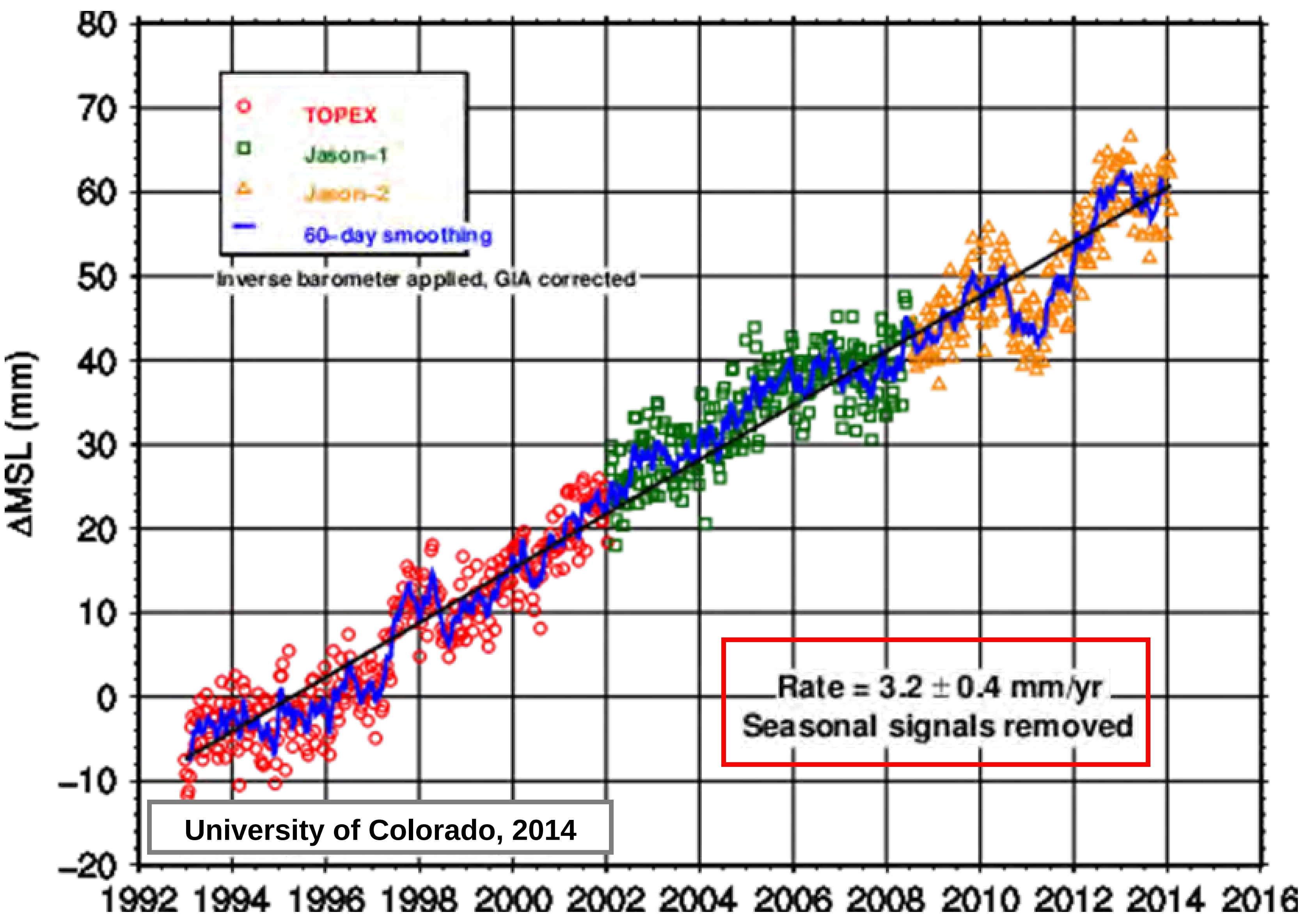

**Adapted from:**
**http://tidesandcurrents.noaa.gov/sltrends/**
**sltrends_station.shtml?stnid=8452660%20Newport,%20RI**

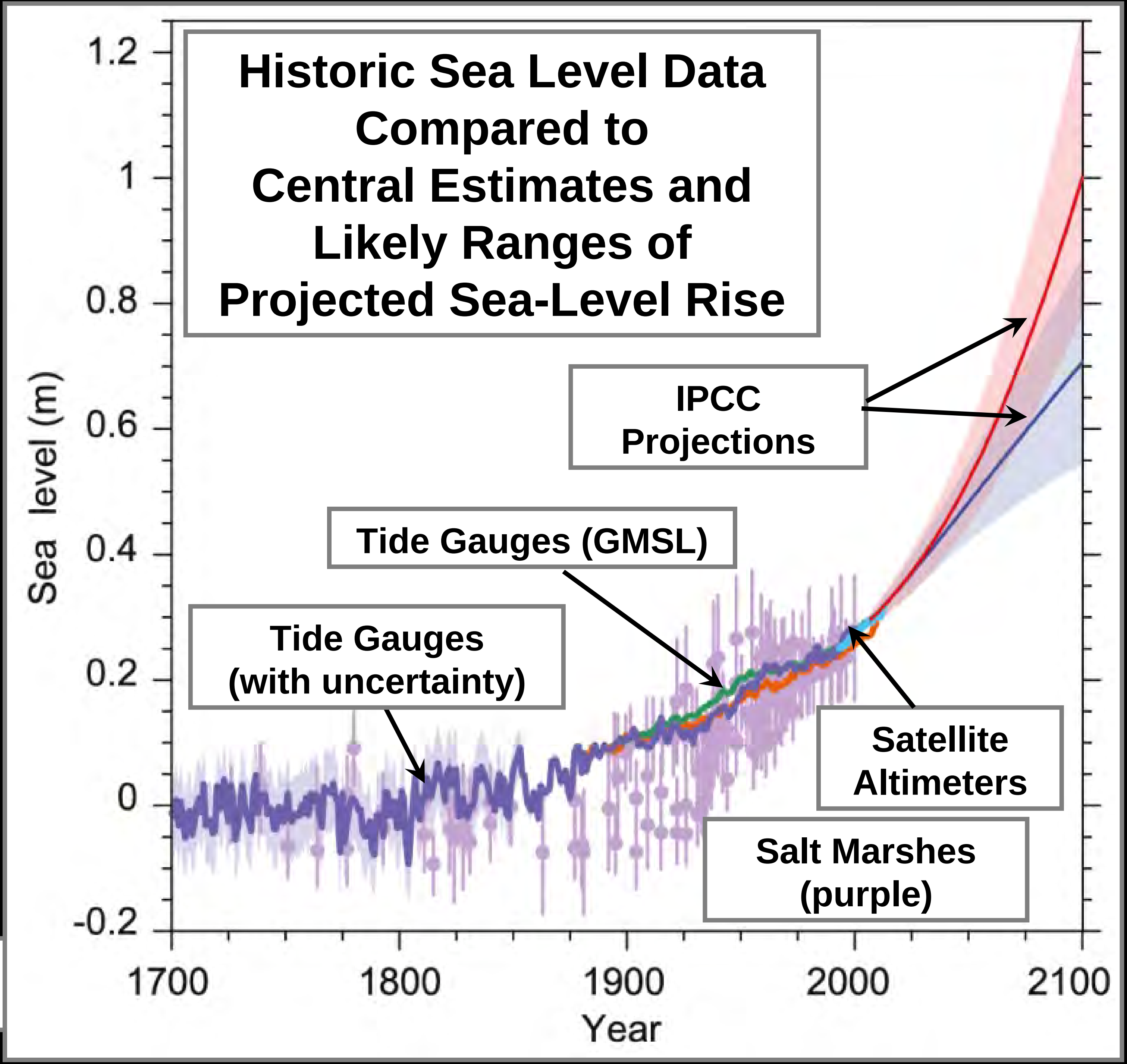
RHODE ISLAND GEOLOGICAL SURVEY

COASTAL HAZARDS GROUP GEOSCIENCES Univ RI

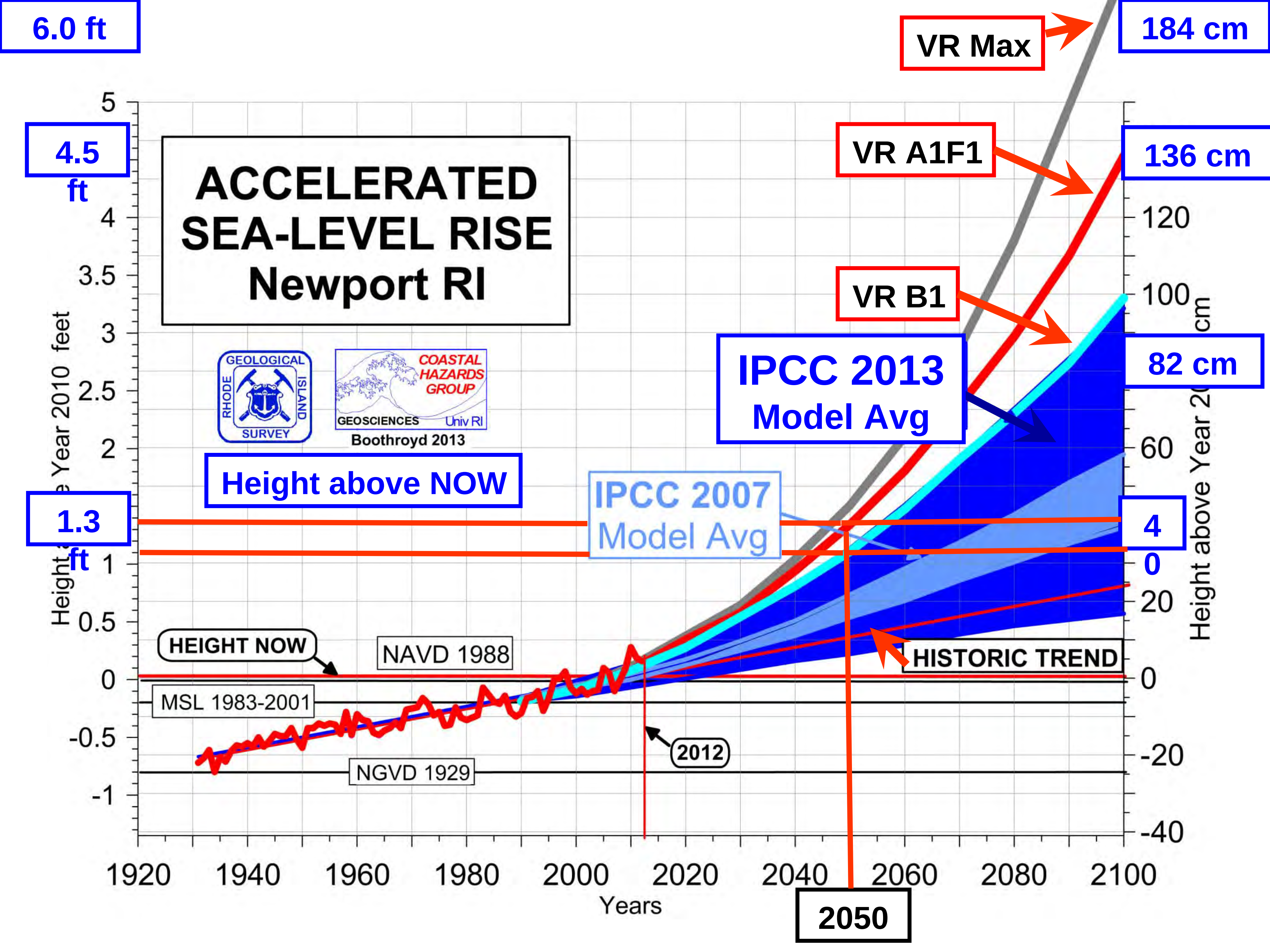
Boothroyd 2013

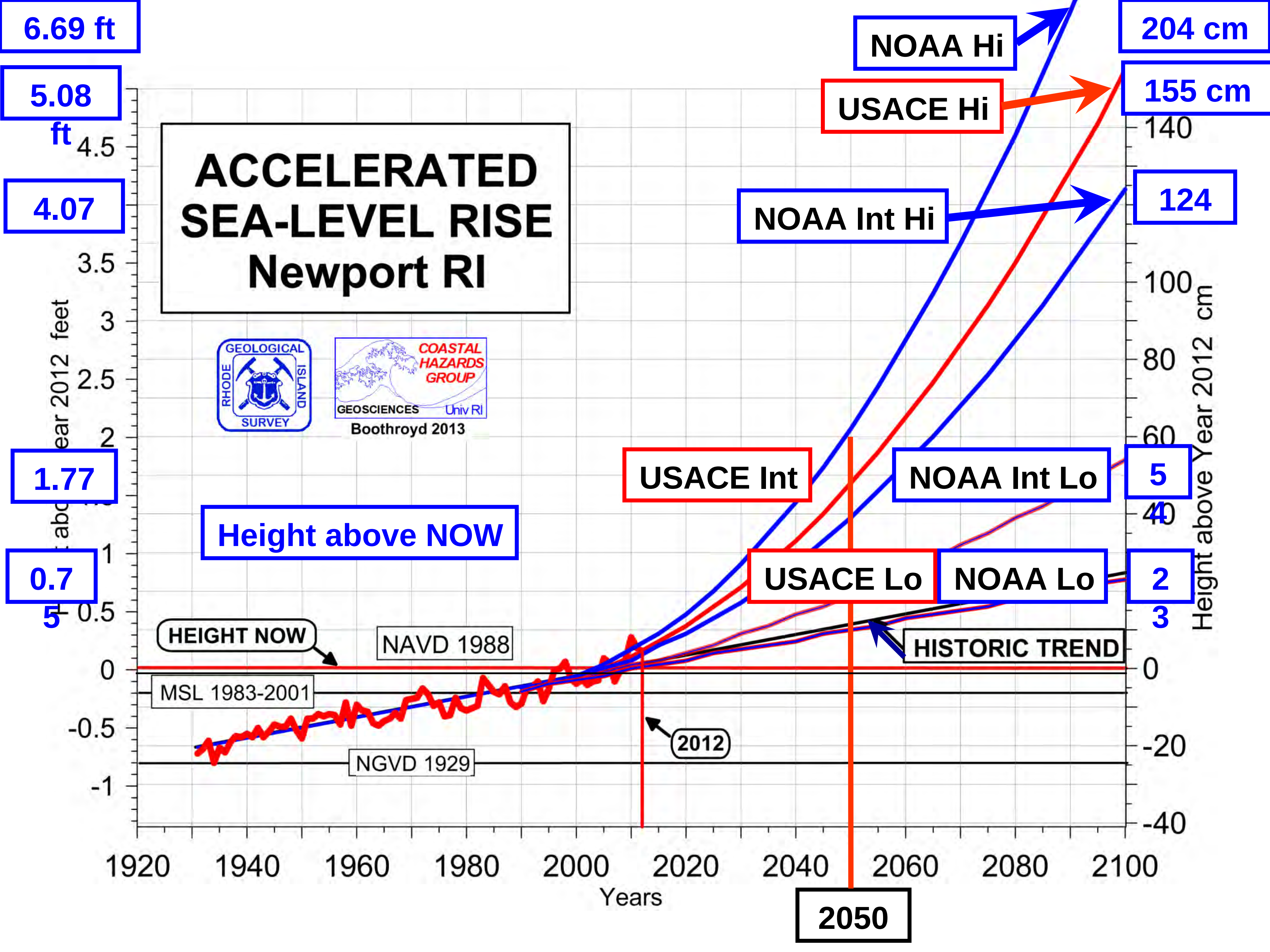
# Global Mean Sea-Level Rise Satellite Altimeters






IPCC 2013,
AR5_fig 13-27

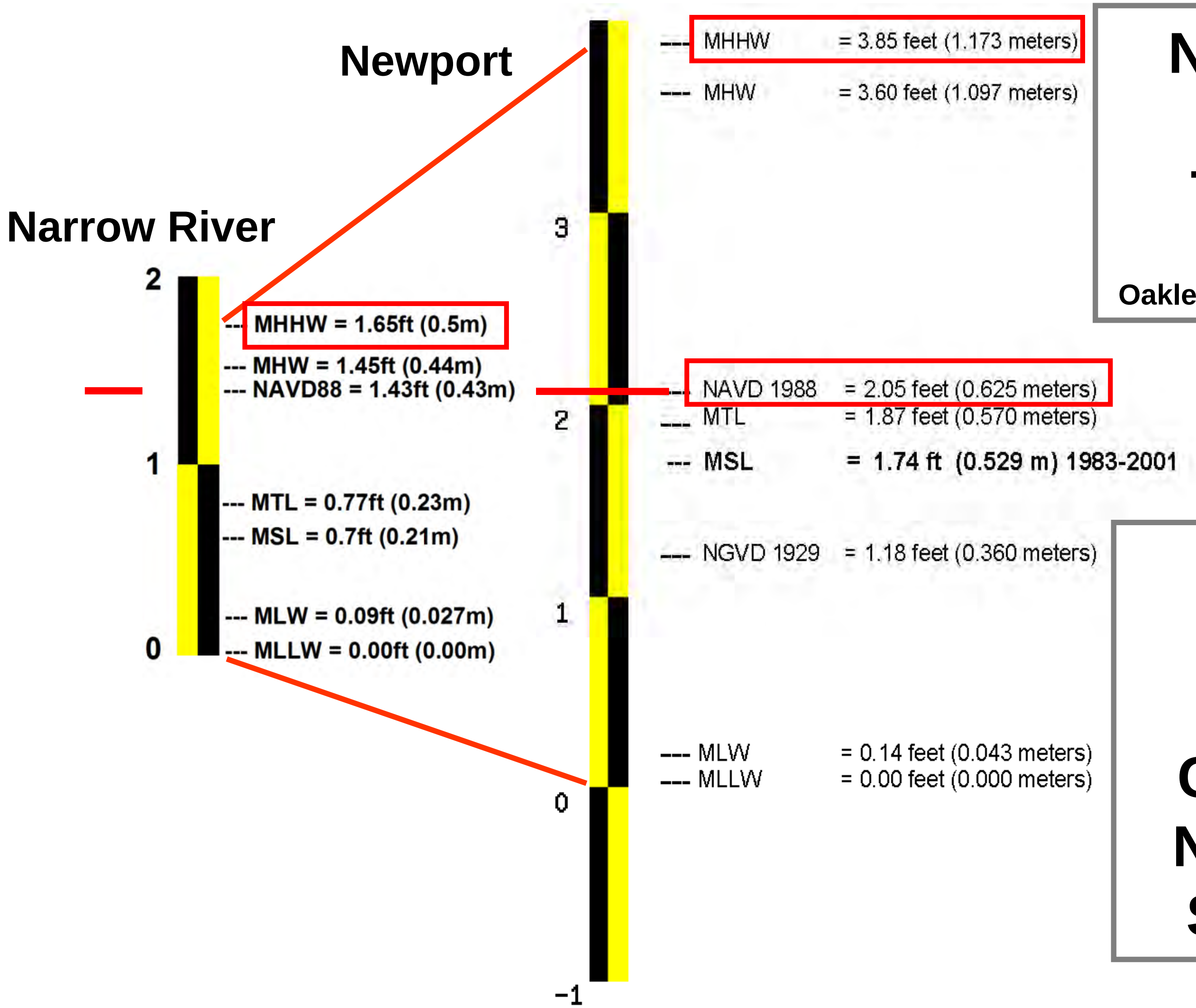

6.0 ft
VR Max
184 cm
4.5
ft
VR A1F1
136 cm
ACCELERATED
SEA-LEVEL RISE
Newport RI
VR B1
IPCC 2013
Model Avg
82 cm
GEOLOGICAL
RHODE
ISLAND
SURVEY
COASTAL
HAZARDS
GROUP
GEOSCIENCES
Univ RI
Boothroyd 2013
Height above NOW
IPCC 2007
Model Avg
1.3
ft
4
0
HEIGHT NOW
NAVD 1988
HISTORIC TREND
MSL 1983-2001
2012
NGVD 1929
5
4
3.5
3
2.5
2
1
0.5
0
-0.5
-1
120
100
60
20
0
-20
-40
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Years
2050
feet
cm
Height above Year 2



ACCELERATED
SEA-LEVEL RISE
Newport RI
GEOLOGICAL
RHODE
ISLAND
SURVEY
COASTAL HAZARDS GROUP
GEOSCIENCES
Univ RI
Boothroyd 2013
6.69 ft
5.08 ft
4.07
1.77
0.75
204 cm
155 cm
124
5
4
2
3
NOAA Hi
USACE Hi
NOAA Int Hi
USACE Int
NOAA Int Lo
USACE Lo
NOAA Lo
HISTORIC TREND
Height above NOW
HEIGHT NOW
NAVD 1988
MSL 1983-2001
NGVD 1929
2012
2050
Years
Height above Year 2012 feet
Height above Year 2012 cm

# Narrow River – Newport Tidal Datums

Oakley, Alvarez and Boothroyd, 2008




GEOLOGICAL RHODE ISLAND SURVEY

## Tidal Range Dependent on Inlet Channel Configuration – Now and Future Sea-Level Rise

The NAVD 1988 and NGVD 1929 elevations related to MLLW were computed from Bench Mark, 845 2660 TIDAL 6, at the station.

Displayed tidal datums are MEAN HIGHER HIGH WATER (MHHW), MEAN HIGH WATER (MHW), MEAN TIDE LEVEL (MTL), MEAN LOW WATER (MLW), AND MEAN LOWER LOW WATER (MLLW) referenced on 1983-2001 Epoch.

**Newport datum adapted from www.ngs.noaa.gov/cgi-bin/ngs_opsd?PID=LW0493**

# PETTAQUAMSCUTT COVE – Flood-Tidal Delta

# Frontal Erosion and the Role of Overwash – Yields Platforms for Marsh Growth with Sea-Level Rise

# Pre-Sandy – Quonochontaug Barrier
## Conservation Land


Bousquet and Son – Aerial Views

# Post-Sandy – Quonochontaug Barrier Conservation Land

# Washover Fan Deposition
# Misquamicut Barrier - Westerly


RI DOT

30 Oct 2012

# Sea-Level Rise

## ---------

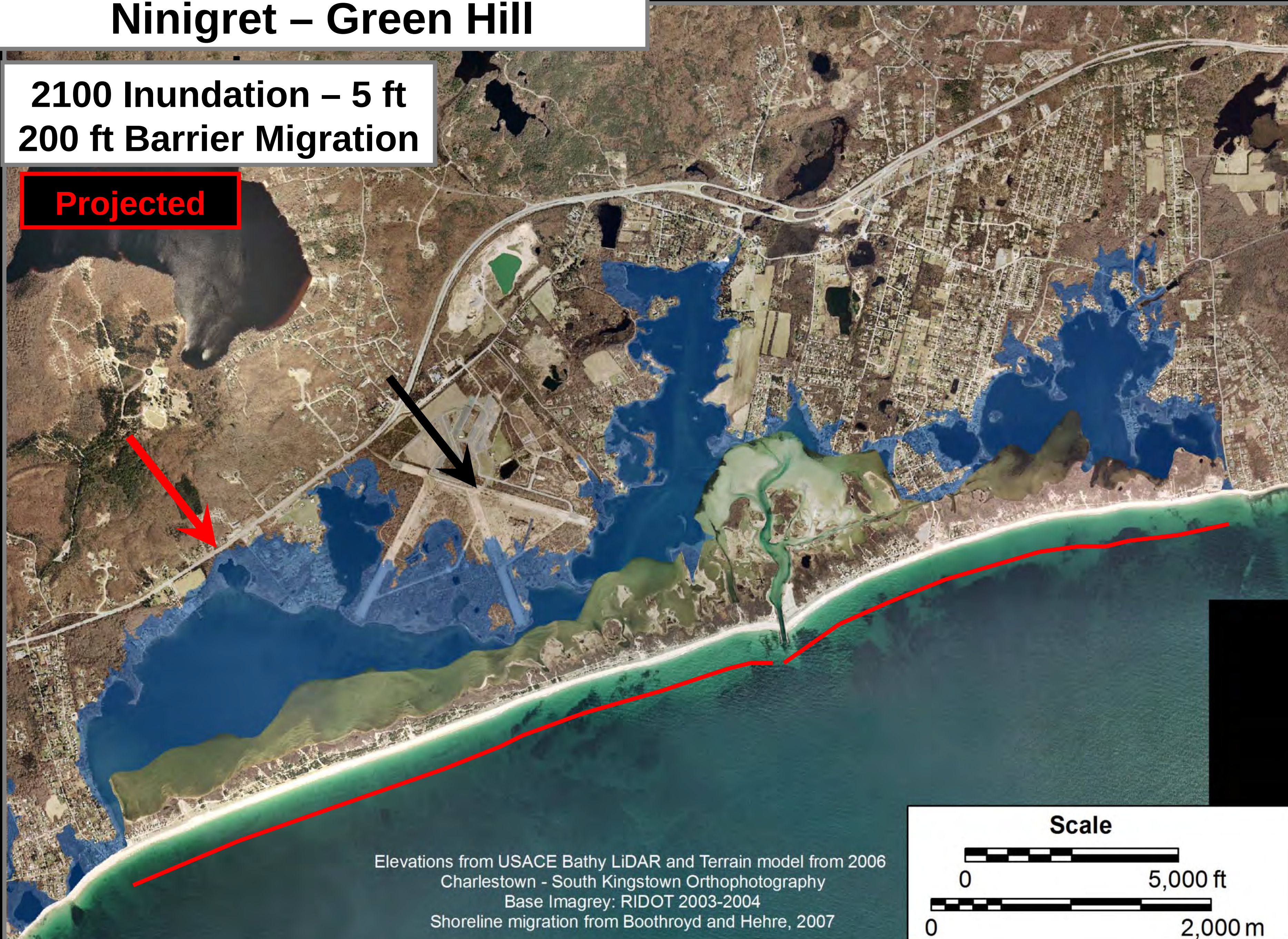
## Permanent Inundation

## Relocation of
## Geologic Habitats Landward
## and
## Upward

# Ninigret – Green Hill Lagoons

## 2003 – 2004 Orthophoto

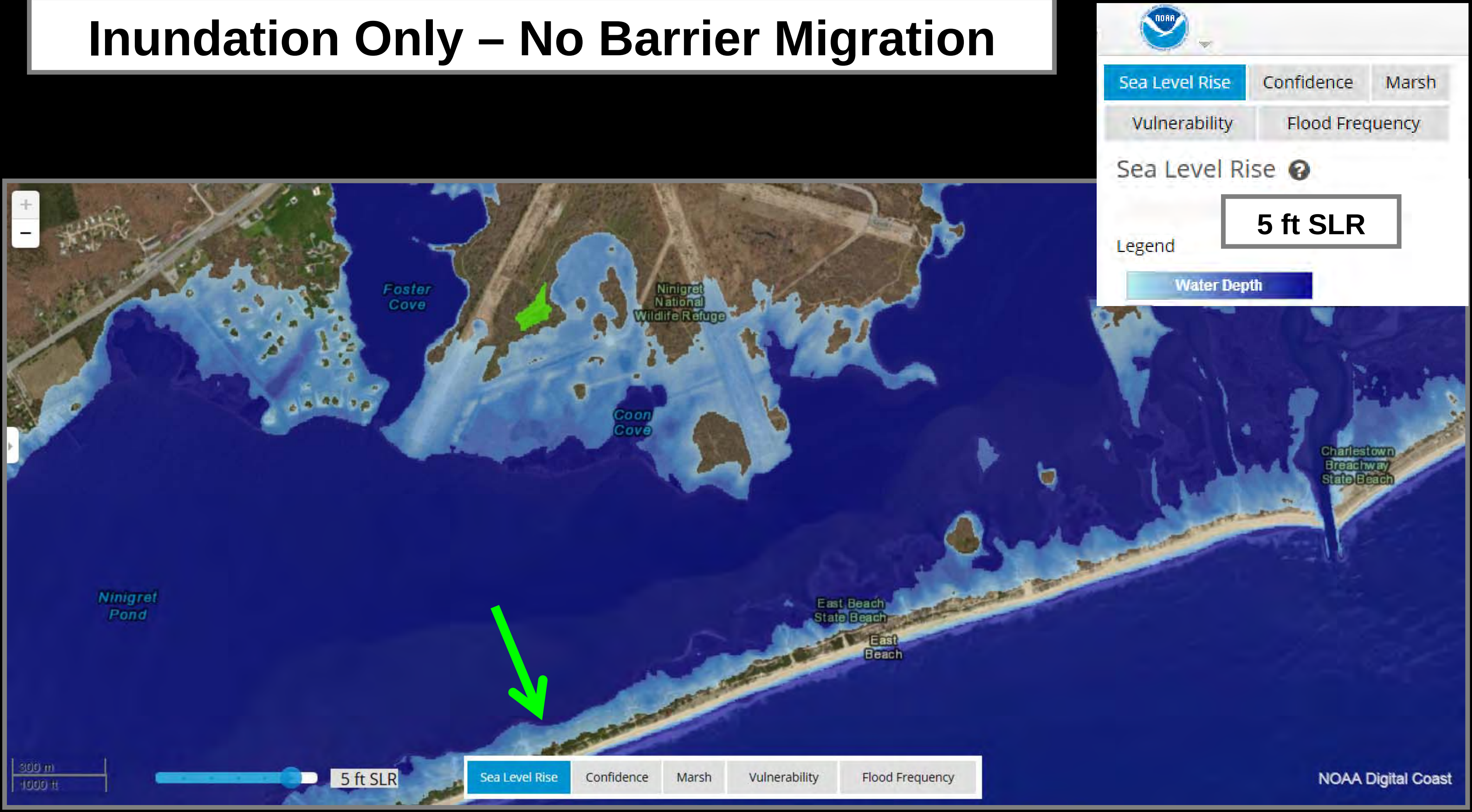
# Ninigret – Green Hill



# Ninigret – Green Hill

# NOAA Sea Level Rise and Coastal Flooding Impacts Viewer

## Inundation Only – No Barrier Migration



# Wickford Marketplace – In-Place Inundation “The Bathtub Ring”

## No Place to Migrate


28 Oct 2011

MelissaDevine9

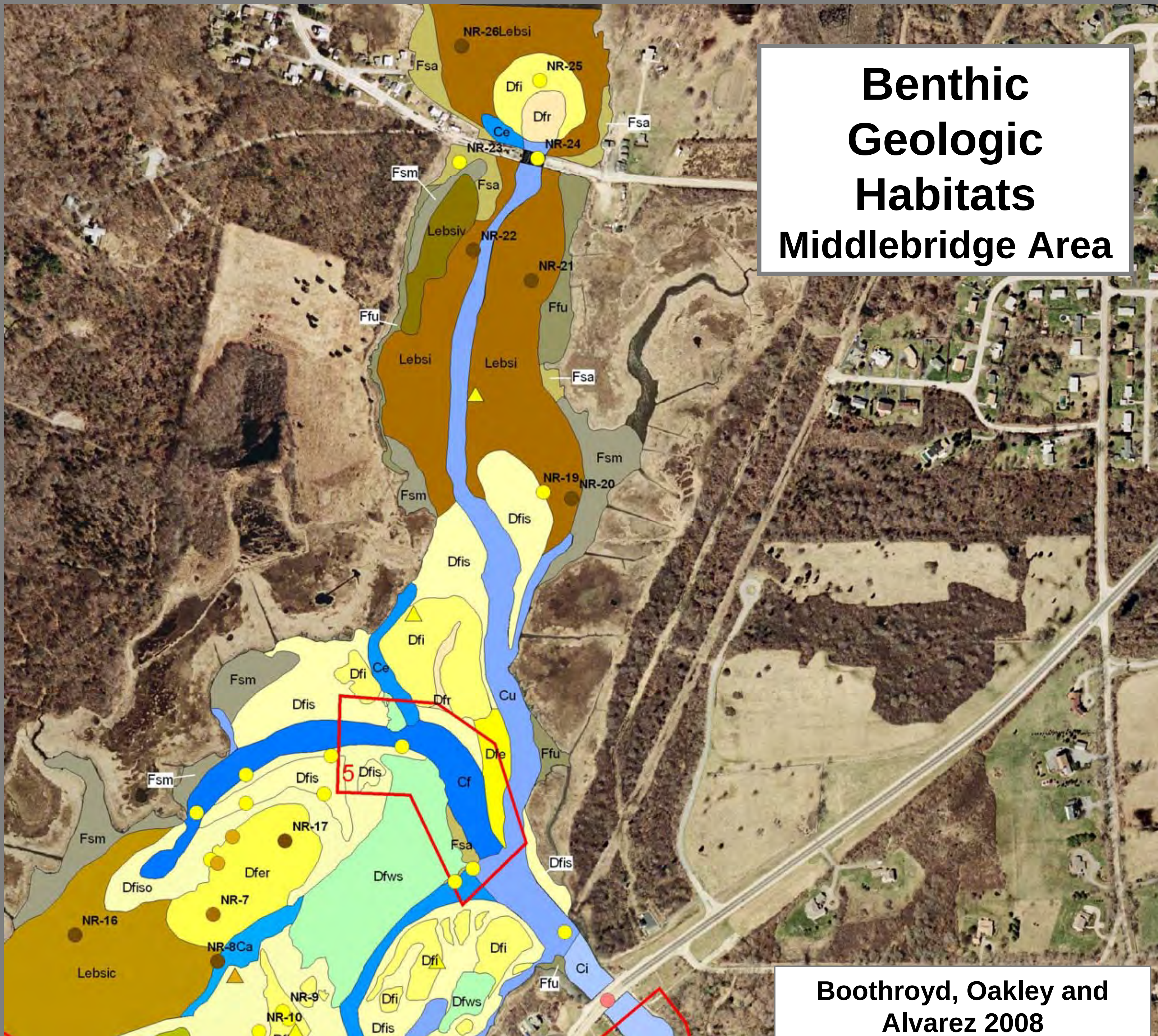
# USDA/NRCS Pontoon boat R/V Doerner “in” Narrow River


B Oakley, 2007

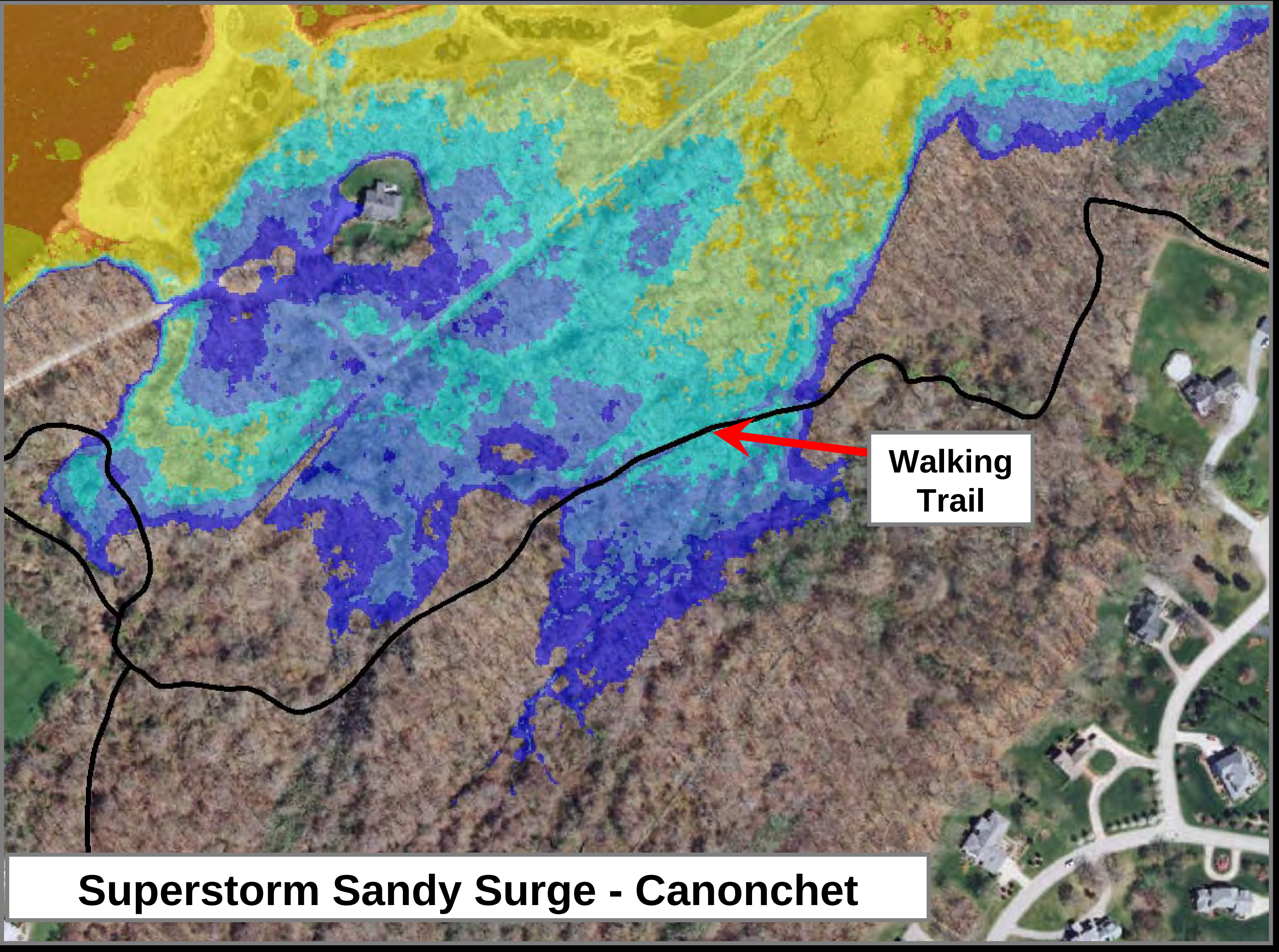
# End of Presentation

# NOAA Sea Level Rise and Coastal Flooding Impacts Viewer

# Benthic Geologic Habitats
## Middlebridge Area

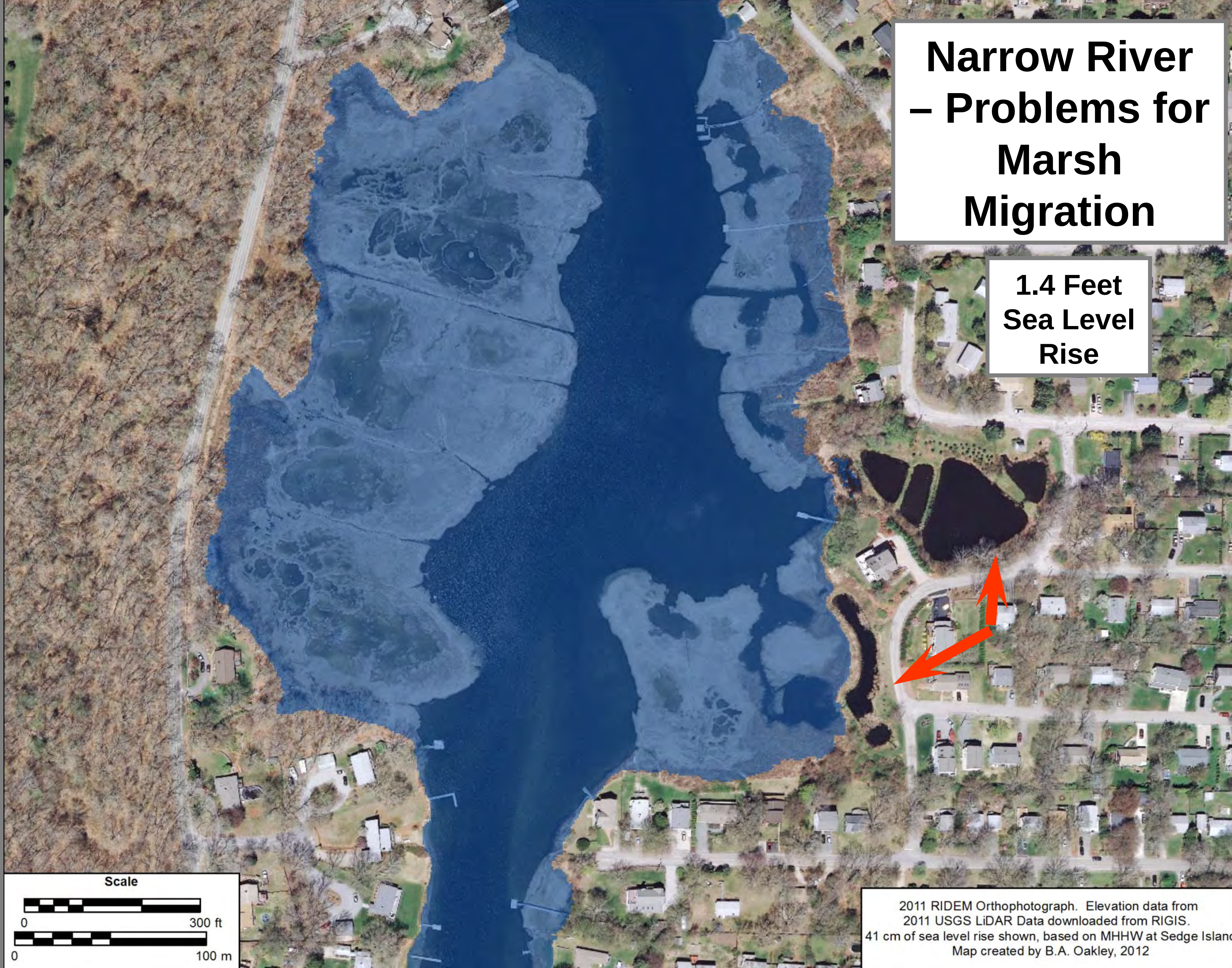



Boothroyd, Oakley and Alvarez 2008

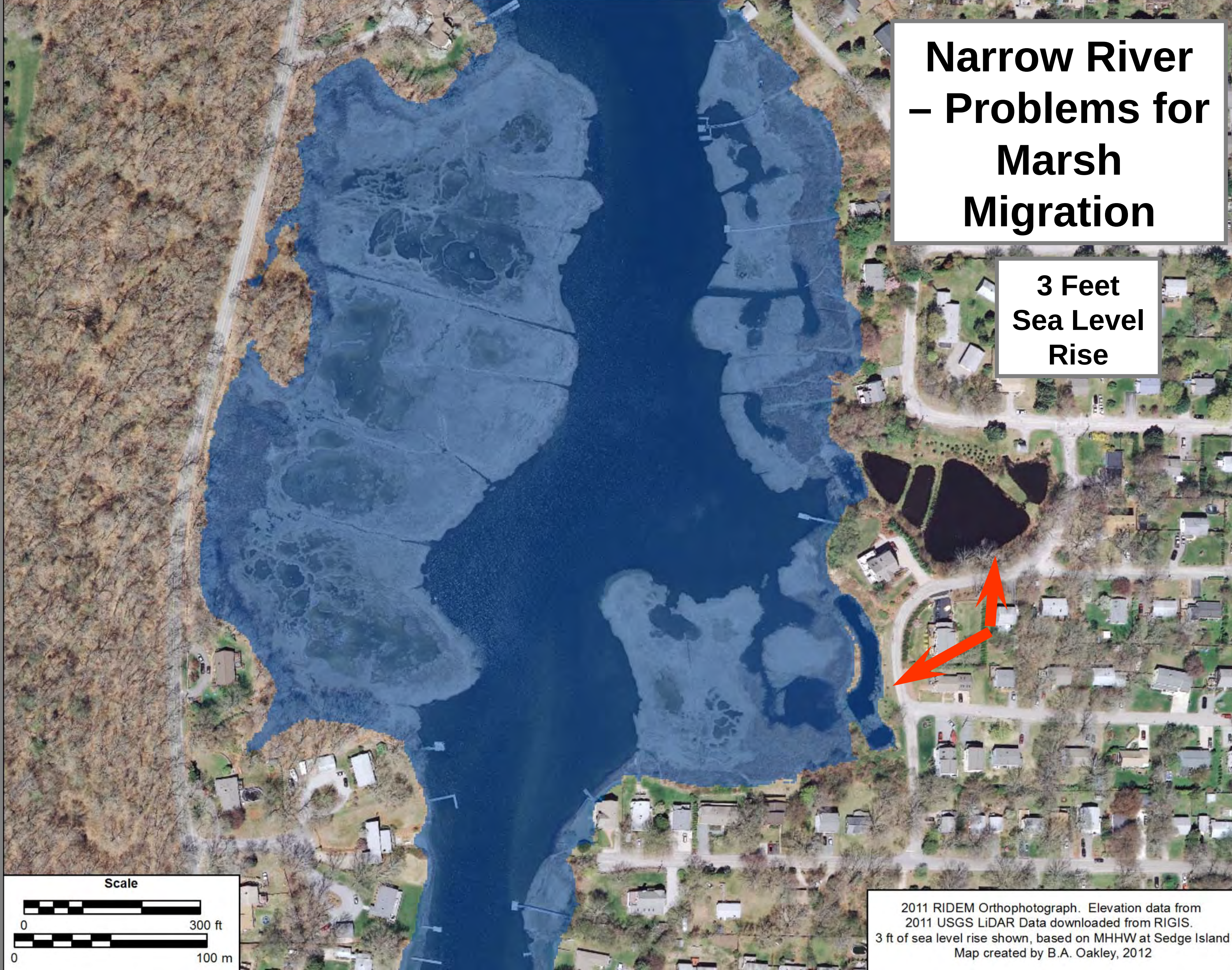



Superstorm Sandy Surge - Canonchet

# Barrier Migration - Creation of Platform for Fringing Marsh

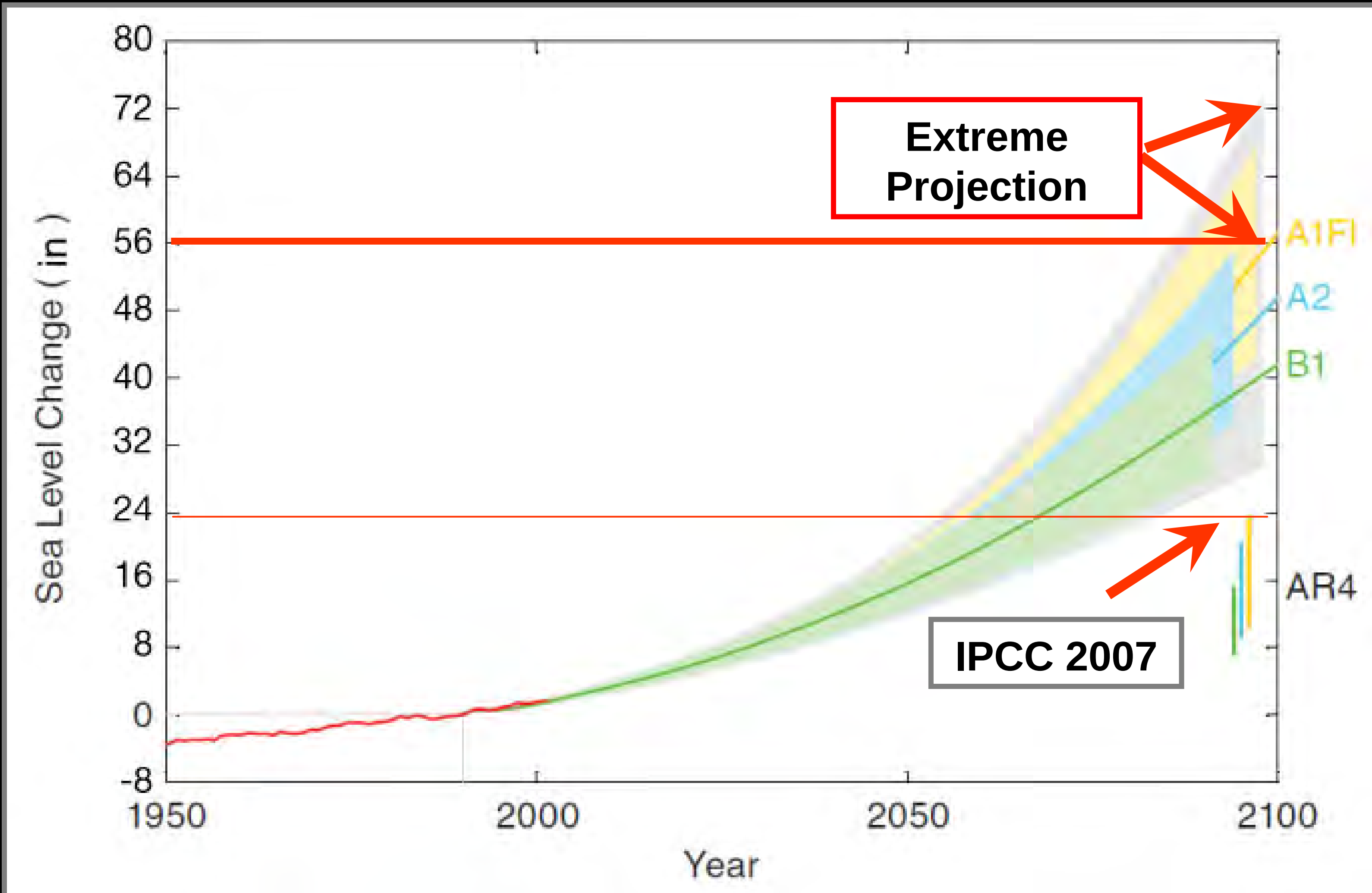


Narrow River – Problems for Marsh Migration
1.4 Feet Sea Level Rise
Scale
0 300 ft
0 100 m
2011 RIDEM Orthophotograph. Elevation data from 2011 USGS LiDAR Data downloaded from RIGIS.
41 cm of sea level rise shown, based on MHHW at Sedge Island
Map created by B.A. Oakley, 2012


Narrow River – Problems for Marsh Migration
3 Feet Sea Level Rise
Scale
0
300 ft
0
100 m
2011 RIDEM Orthophotograph. Elevation data from
2011 USGS LiDAR Data downloaded from RIGIS.
3 ft of sea level rise shown, based on MHHW at Sedge Island
Map created by B.A. Oakley, 2012

Narrow River – Problems for Marsh Migration
5 Feet Sea Level Rise
Scale
0
300 ft
0
100 m
2011 RIDEM Orthophotograph. Elevation data from
2011 USGS LiDAR Data downloaded from RIGIS.
5 ft of sea level rise shown, based on MHHW at Sedge Island
Map created by B.A. Oakley, 2012

# Accelerated Sea-Level Rise Linked to Global Temperature Increase – A Semi-Empirical Model




Vermeer and Rahmstorf (PNAS 2009)

# A declining role of organic matter in contributing to Narragansett Bay salt marsh accretion

Joanna C. Carey
U.S. Environmental Protection Agency

RI Salt Marsh Workshop
Providence, RI
April 16, 2014

*Nag West, NBNERR*

# A unique opportunity

Estuaries Vol. 12, No. 4, p. 300–317 December 1989

## Accretion Rates and Sediment Accumulation in Rhode Island Salt Marshes

S. Bricker-Urso
S. W. Nixon
*Graduate School of Oceanography*
*University of Rhode Island*
*Narragansett, Rhode Island 02882*

J. K. Cochran
D. J. Hirschberg
*Marine Sciences Research Center*
*State University of New York*
*Stony Brook, New York 11794*

C. Hunt
*Battelle Ocean Sciences*
*Duxbury, Massachusetts 02332*

Have rates changed in 30 years?

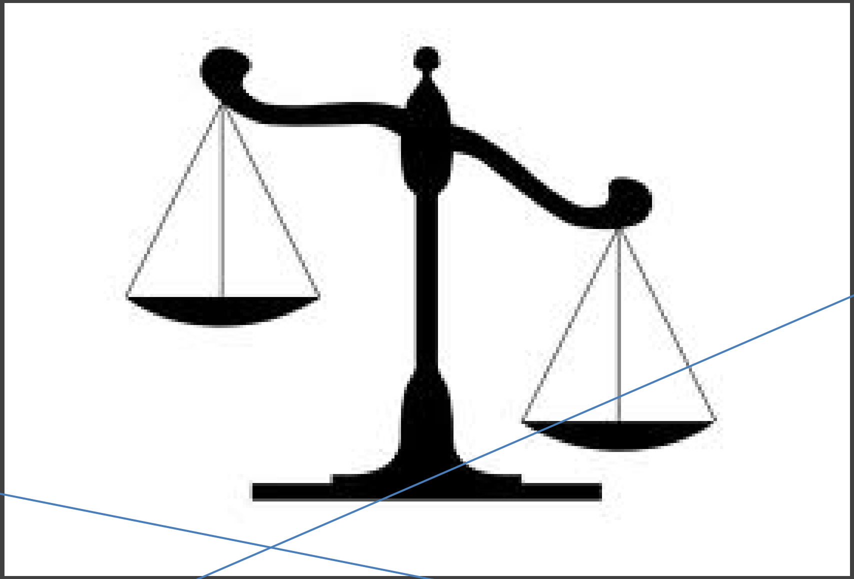
# A few marsh accretion basics

Organic and inorganic means

Sediment Deposition

and

Primary Production



Erosion

and

Decomposition

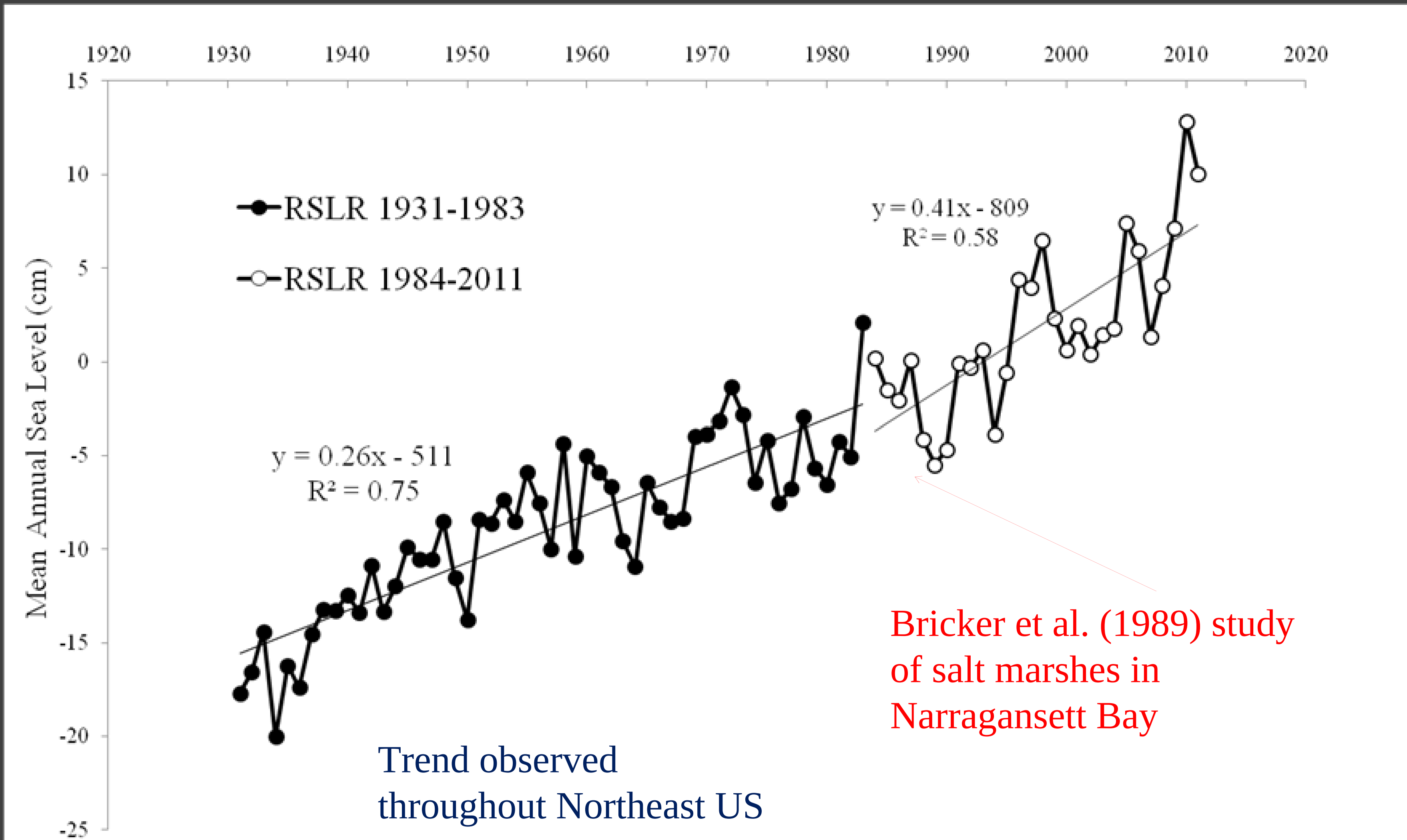
River runoff
Watershed management
Storm surges
Precipitation

**Other Factors**
Compaction, Subsidence

Nutrients
Salinity
Waterlogging
Temperature

Marshes typically keep up with SLR (over last 4000 yrs)

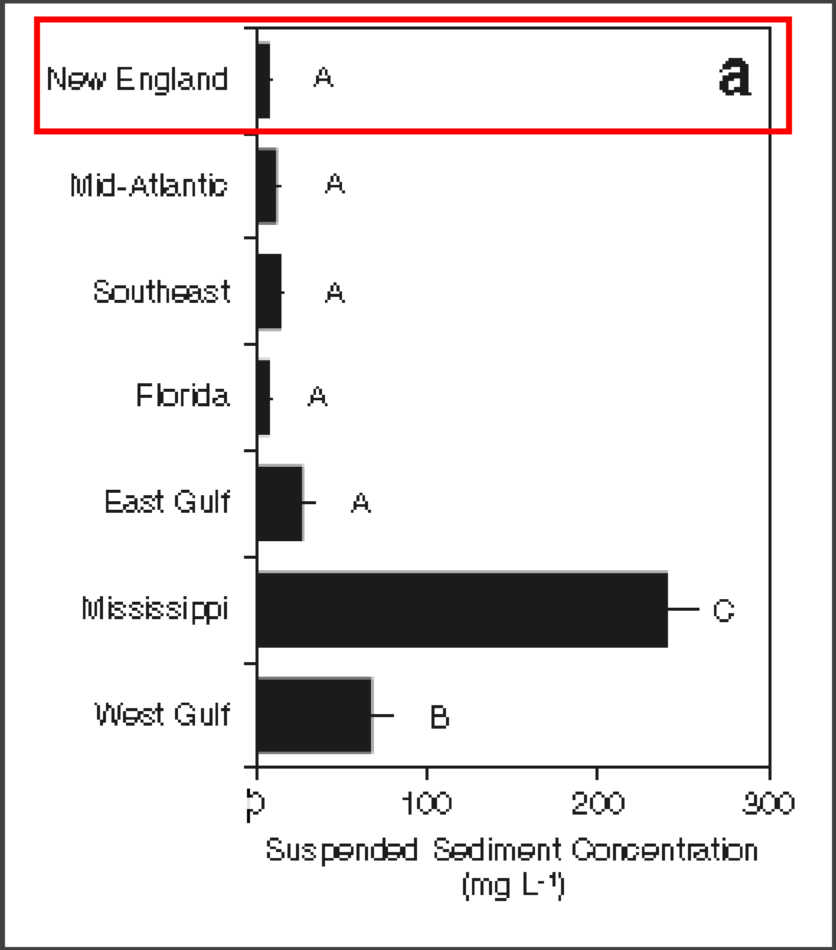
# Sea level rise in Narragansett Bay

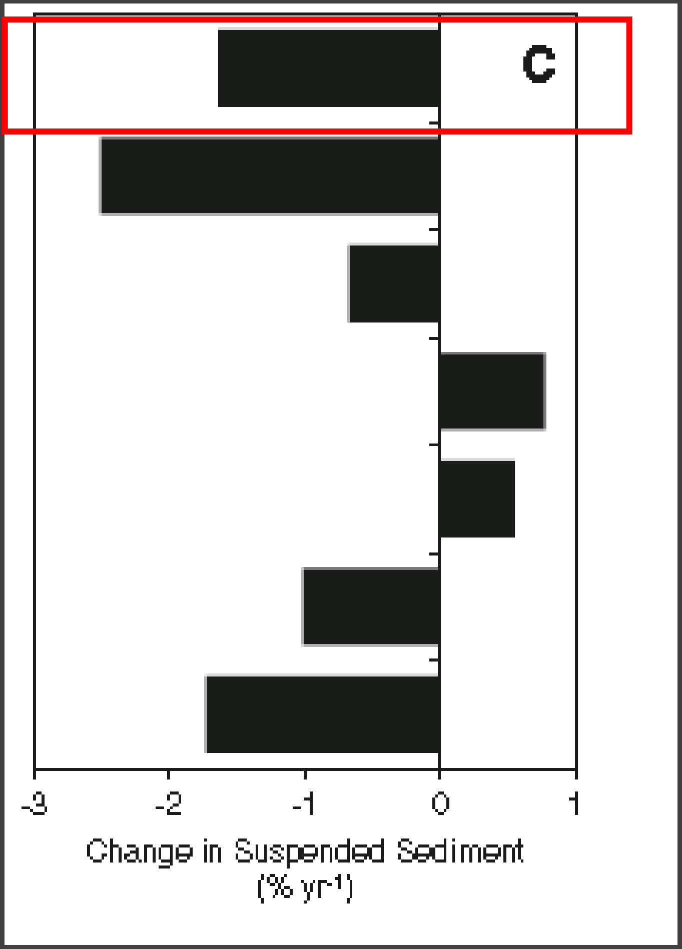


Estuaries and Coasts
DOI 10.1007/s12237-013-9654-8

# Declining Sediments and Rising Seas: an Unfortunate Convergence for Tidal Wetlands

Nathaniel B. Weston



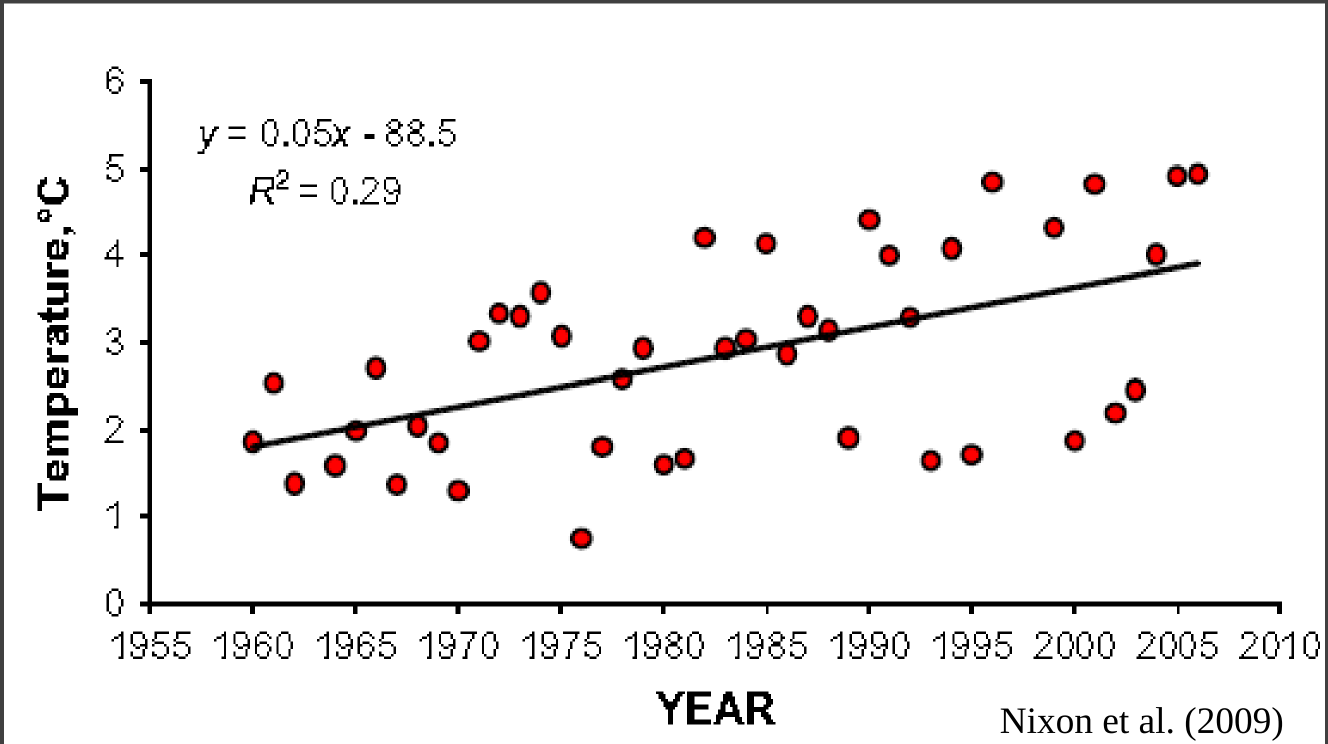

New England has low sediment loads

*organic matter plays especially important role in accretion*

New England sediment loads are declining (since mid '70s)

*Weston 2014*

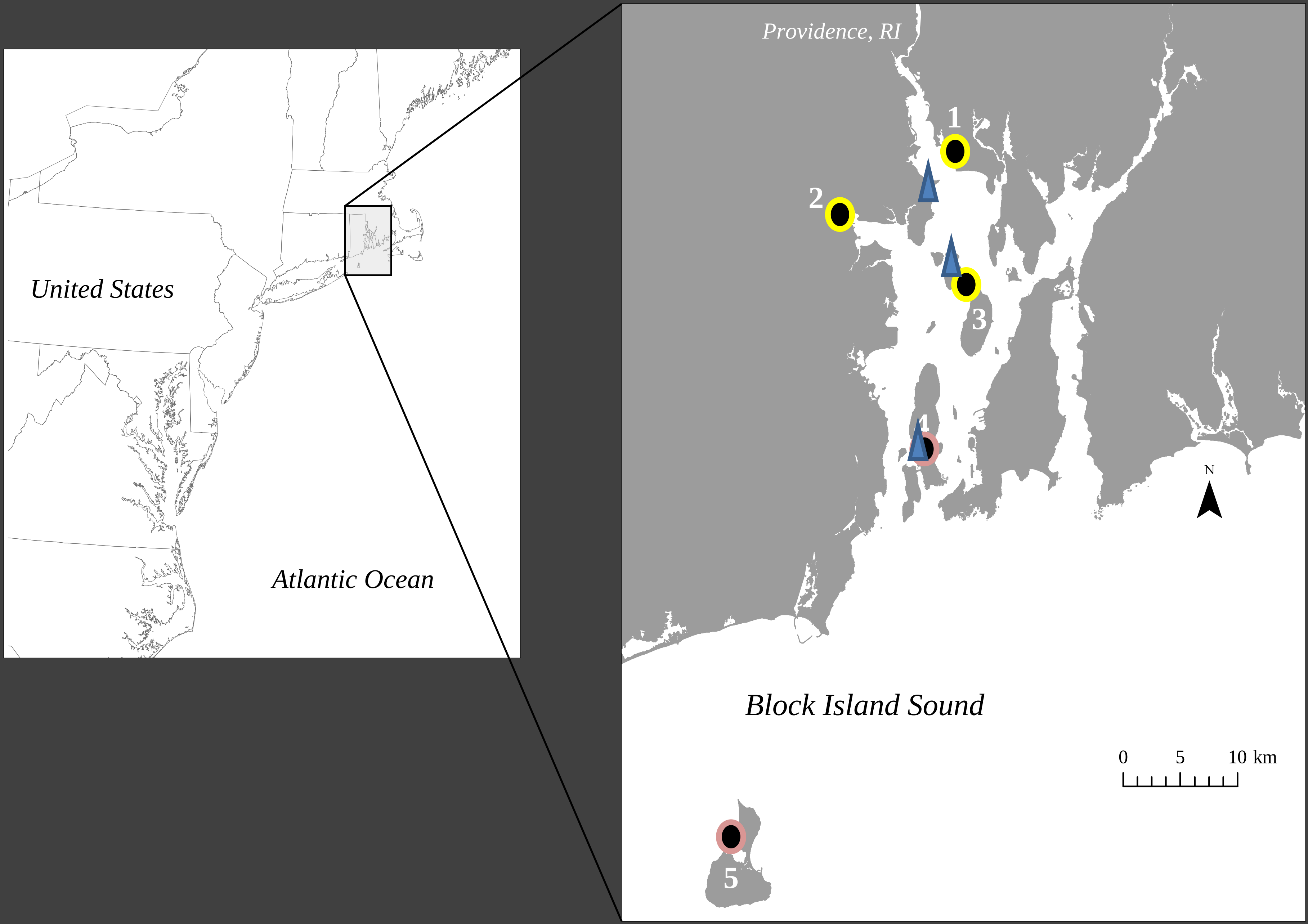
# Temperature also changing in sea and air




Nixon et al. (2009)

Warmer water temperatures – winter temperature increased 2.2 ˚C since 1960 (Nixon et al. 2009)

Warmer air temperatures in New England - 0.25 ˚C per decade since 1970 (Hayhoe et al. 2007)


United States
Atlantic Ocean
Providence, RI
1
2
3
4
5
Block Island Sound
N
0
5
10 km

# Accretion Rates in Salt marshes

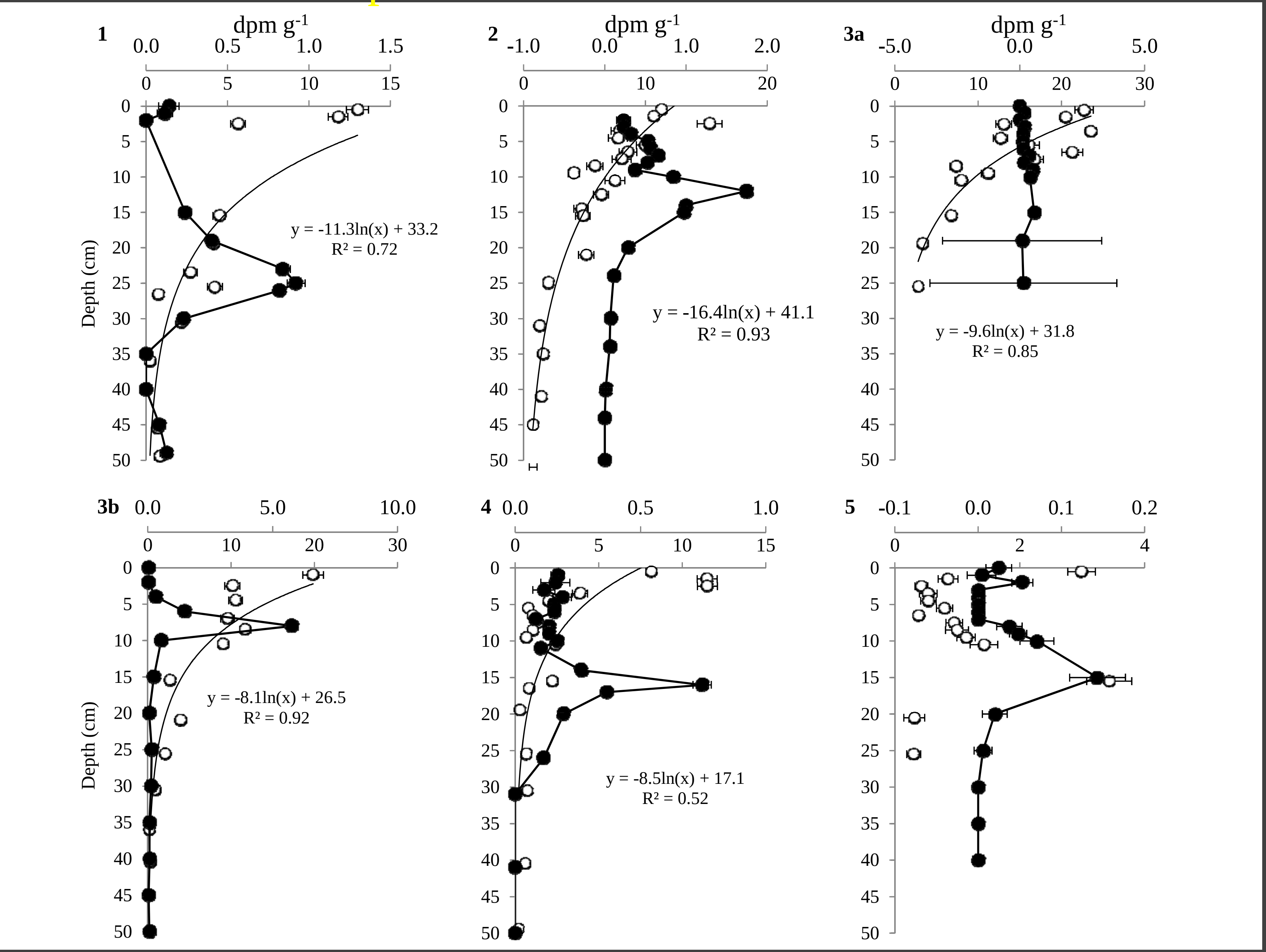
Took sediment cores 5 marshes (revisit 3 same sites as Bricker et al. (1989)

Cores taken from low marsh all sites and also high marsh at NBNERR Site

Used radionuclide tracers ($^{137}$Cs and $^{210}$Pb (gamma counts)) to determine age of sediments at different depths (Moran Lab, GSO)

Determined role of inorganic vs organic material in driving accretion rates

# Geochemical profiles of radio nuclide tracers in sediment




Top axis = $^{137}$Cs, bottom axis = $^{210}$Pb

black circles= $^{137}$Cs, white circles = $^{210}$Pb

# Results

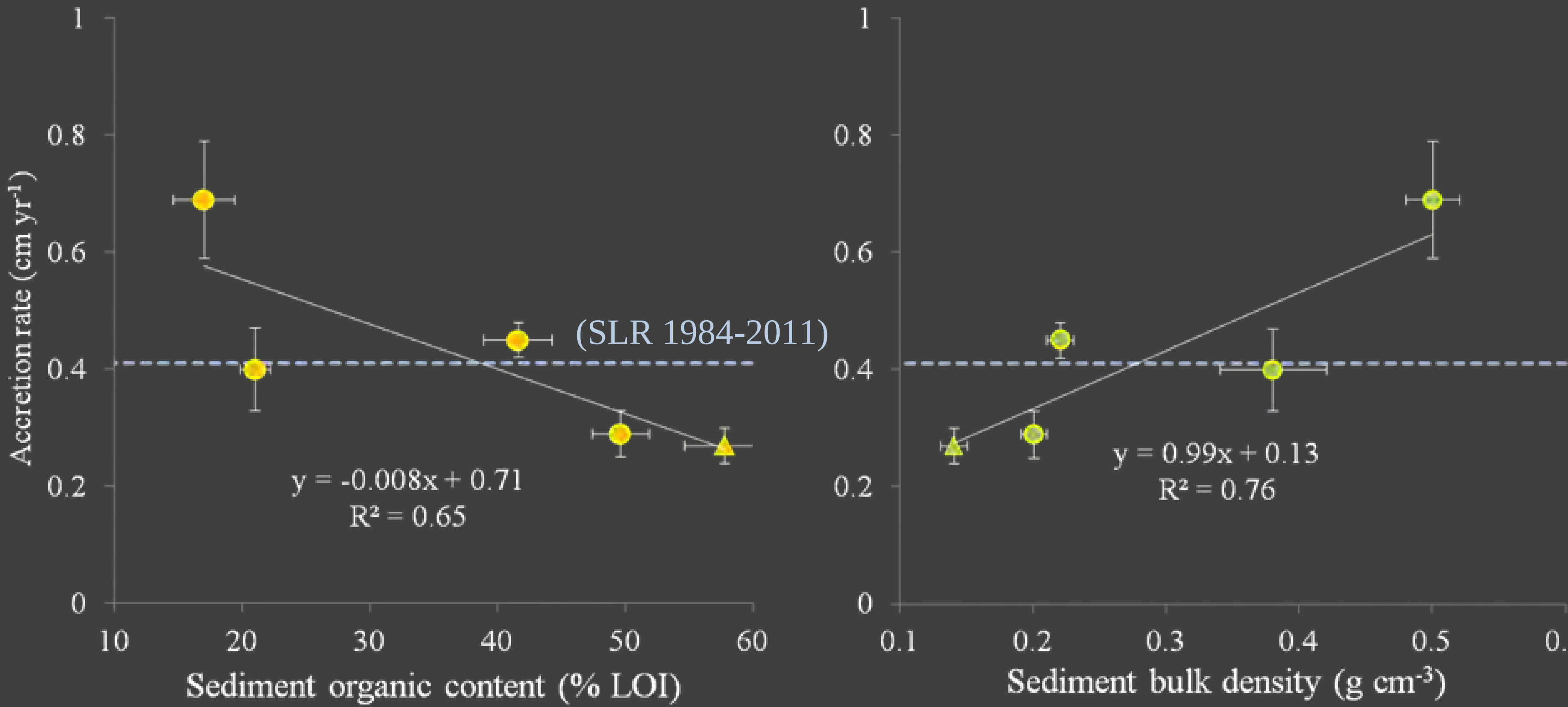
| Site | Accretion rates (cm yr$^{-1}$) Historical[1] | | This study | | |
|---|---|---|---|---|---|
| | $^{210}$Pb* | $^{210}$Pb* | $^{210}$Pb** | [illegible] | $^{137}$Cs |
| 1 | 0.55 ± 0.06 | 0.40 ± 0.07 | 0.49 ± 0.30 | [illegible] | 0.52 |
| 2 | na | 0.45 ± 0.03 | 0.55 ± 0.04 | [illegible] | 0.25 |
| 3a | 0.60 ± 0.02 | 0.29 ±0.04 | 0.35 ± 0.04 | [illegible] | 0.34 |
| 3b | 0.24 ± 0.02 | 0.27 ± 0.03 | 0.27 ± 0.05 | [illegible] | 0.17 |
| 4 | 0.37 ± 0.02 | 0.69 ± 0.10 | 0.51 ± 0.15 | [illegible] | 0.33 |
| 5 | na | ~~1.03 ± 0.18~~ | 1.16 ± 1.27 | [illegible] | 0.31 |

*Derived from CRS model, **Derived from CIC model

**Some marshes accreting faster, other slower compared to historical measurements**

**Need to look at rates vs. RSLR and *how* these marshes are accreting**

# Marsh accretion rates as a function of sediment properties




More organic-rich marshes are less able to keep up with sea level rise

# Organic matter accounts for less accretion

| | This Study | | Historical[6] | |
|---|---|---|---|---|
| | Accretion (%) via | | Accretion (%) via | |
| Site | Organic | Inorganic | Organic | Inorganic |
| 1 | 5.2 | 12.4 | 7 | 15 |
| 2 | 8.2 | 4.9 | na | na |
| 3a | 8.8 | 3.8 | 11 | 9 |
| 3b | 7.6 | 2.4 | 11 | 9 |
| 4 | 7.8 | 16.1 | 9 | 9 |
| 5 | 2.1 | 47.2 | na | na |

Organic matter accounting for less of accretion entire Bay = decomposition rates?

Inorganic matter accounting for less of accretion upper Bay = sediment availability?

Waterlogging of Upper Bay Marshes

# Confluence of multiple factors pose risk to salt marshes

Increased rate of RSLR

Increased temperature (increased decomposition rates)

Limited sediment supplies (are supplies declining?)

**Organic-rich, sediment-starved salt marshes appear threatened**

# Acknowledgements

**Co-Authors/Collaborators:** Wally Fulweiler, Brad Moran, Pat Kelly, Alex Kolker

**Field/lab assistance:** Sarah Sargent, Kenny Raposa, Jules Opton-Himmel, Marc Zemel

**Intellectual Generosity:** Scott Nixon, Cathy Wigand

**National Estuarine Research Reserve Graduate Research Fellowship**

BOSTON UNIVERSITY

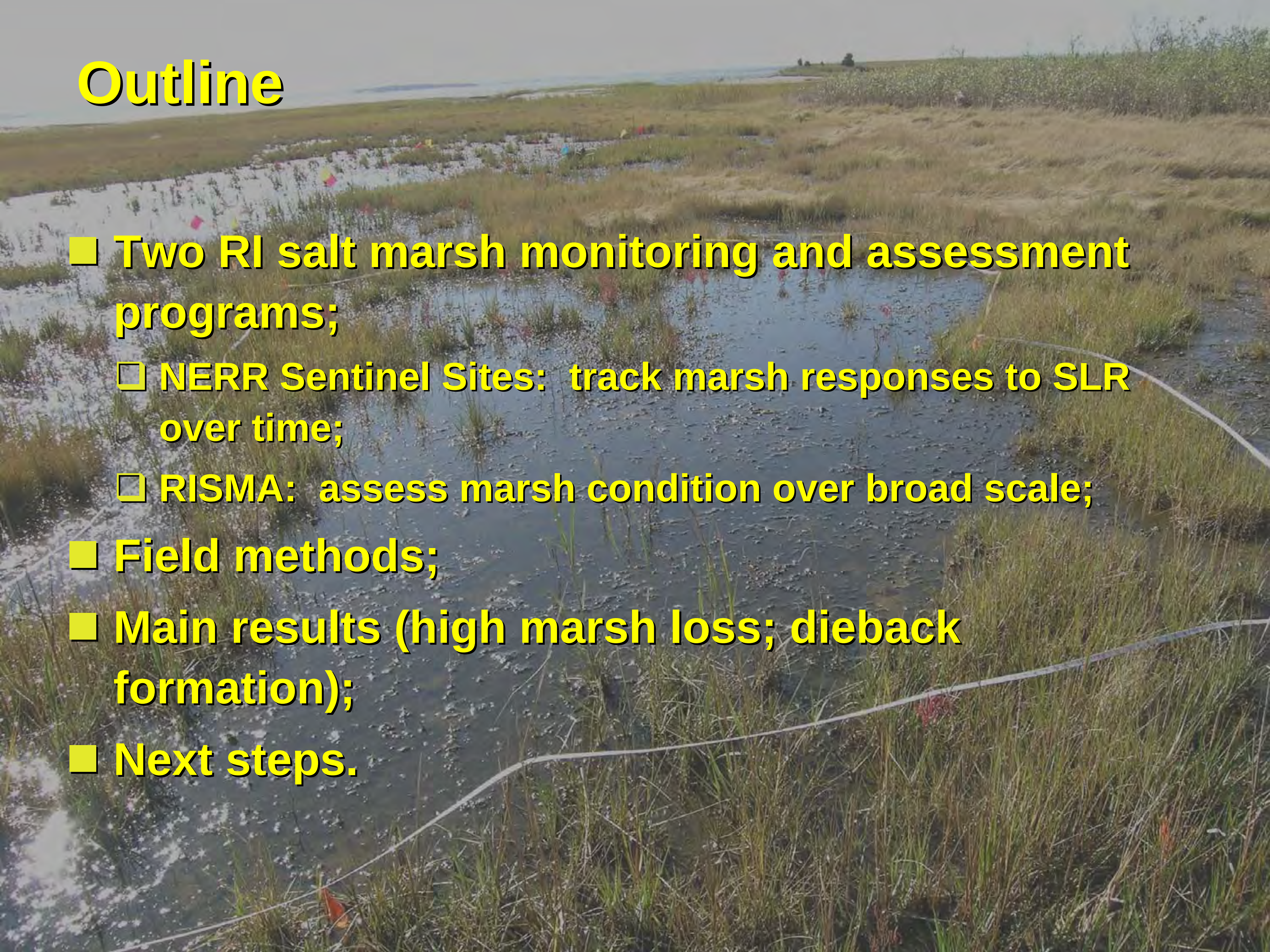
# Dieback events accelerate ongoing *Spartina patens* loss in Rhode Island salt marshes


**Kenneth B. Raposa, Ph.D.**
**Research Coordinator**
**Narragansett Bay NERR**

Narragansett Bay Research Reserve

**Robin Weber; NBNERR Nat. Res./GIS Specialist**
**Daisy Durant, Ph.D.; NBNERR Marine Research Specialist II**
**Marci Cole Ekberg, Ph.D.; Save The Bay Coastal Ecologist**
**Wenley Ferguson; Save The Bay Restoration Coordinator**

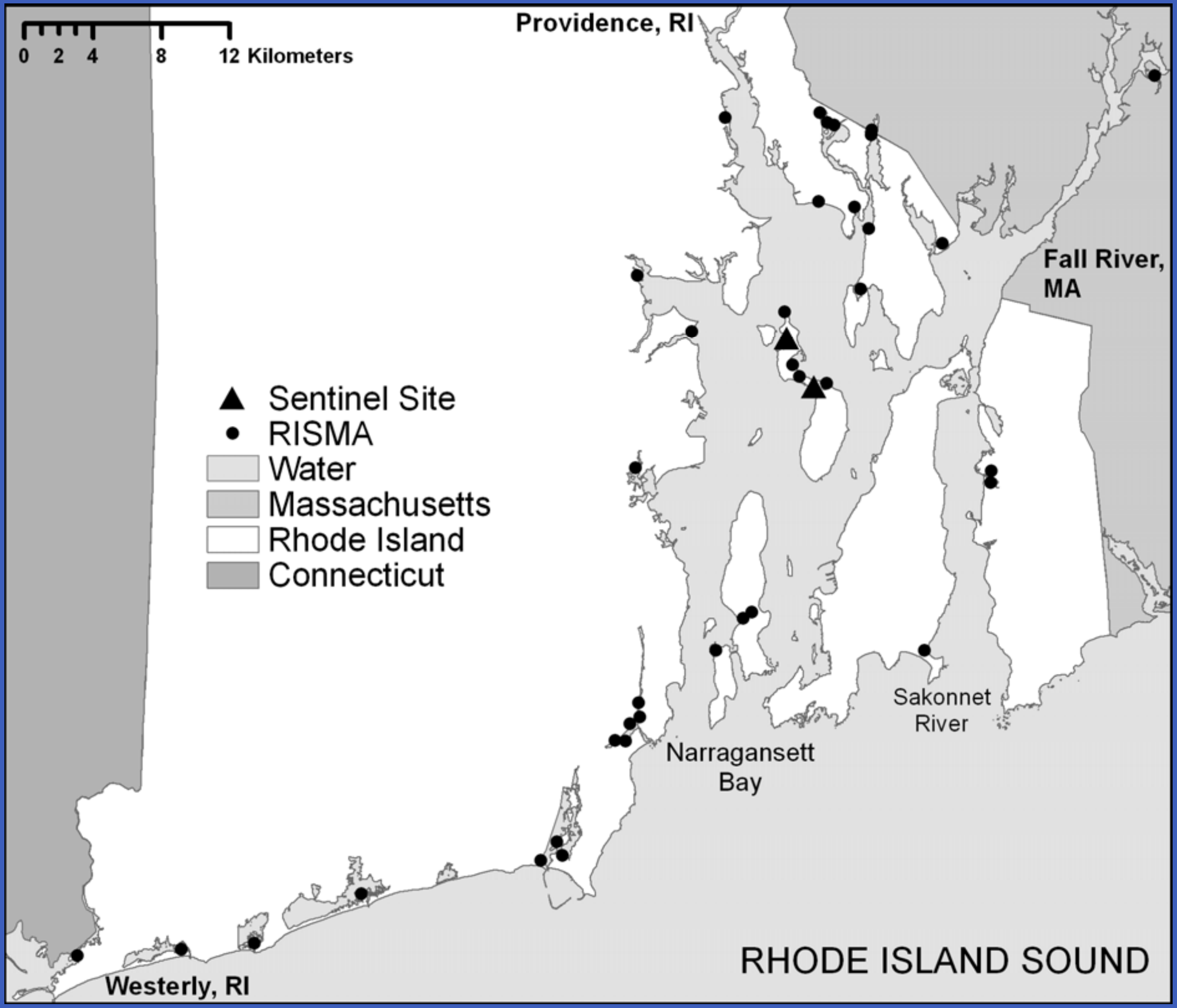
SAVE THE BAY
NARRAGANSETT BAY



# Outline

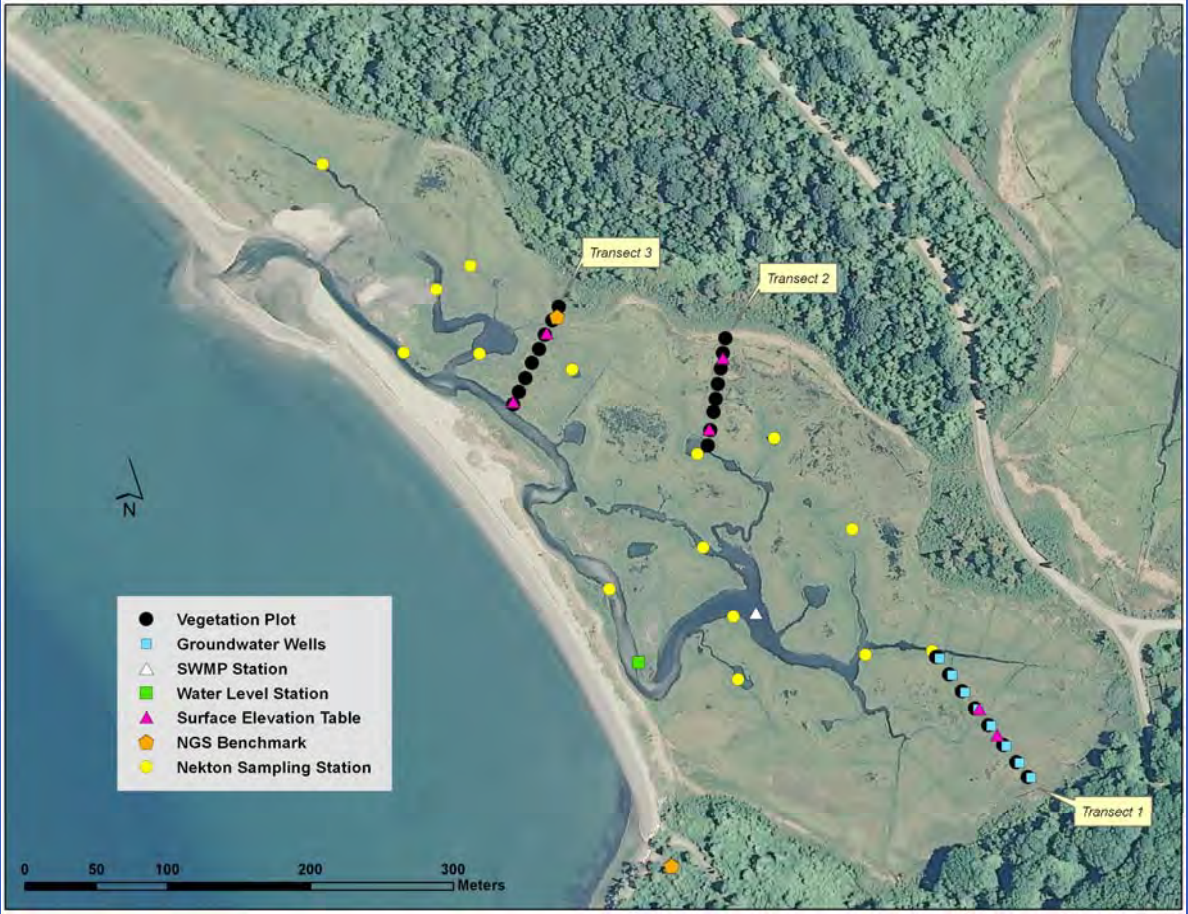
- Two RI salt marsh monitoring and assessment programs;
  - NERR Sentinel Sites:  track marsh responses to SLR over time;
  - RISMA:  assess marsh condition over broad scale;
- Field methods;
- Main results (high marsh loss; dieback formation);
- Next steps.

# Geographic Setting and Study Area



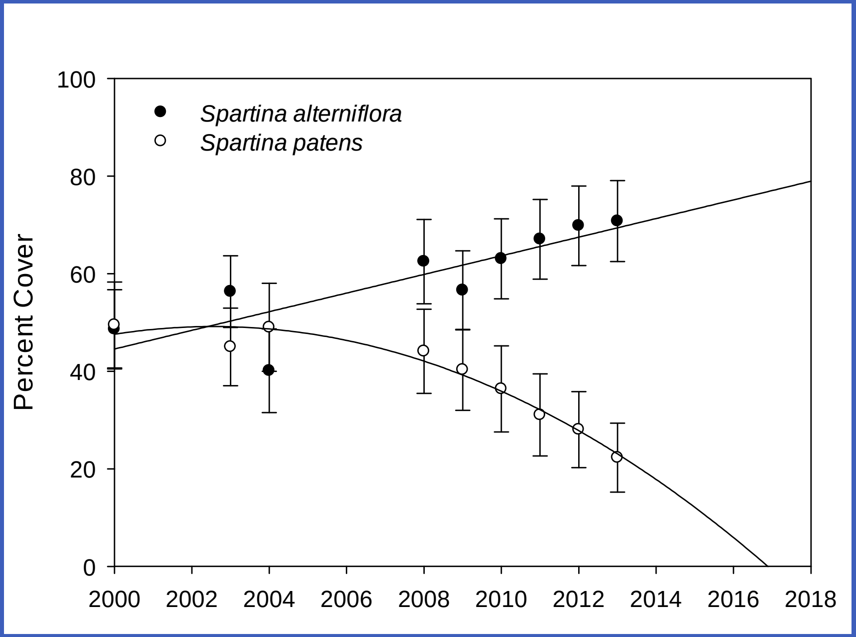
# Methods – NBNERR Sentinel Sites

- Vegetation monitoring
- RTK elevation surveys
- RTK habitat surveys
- SETs
- Water levels

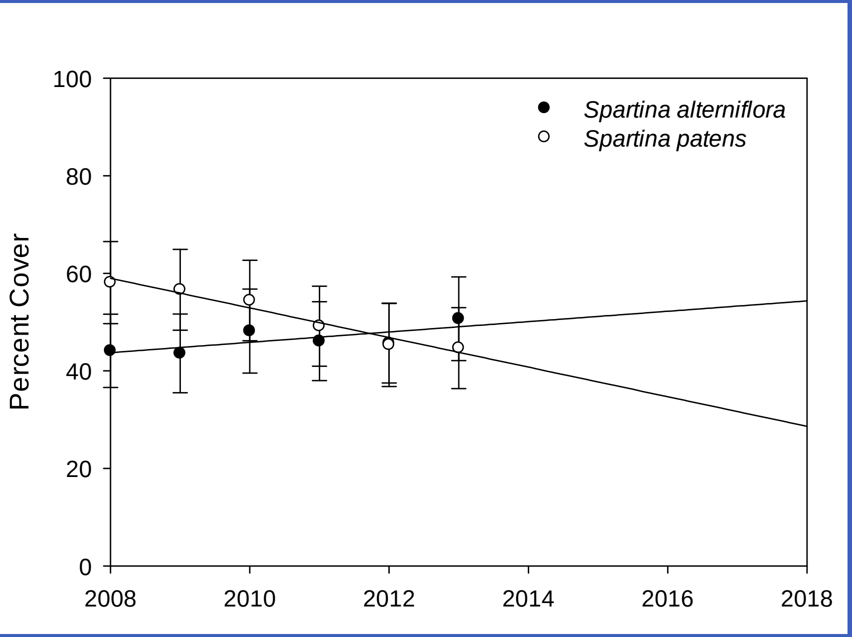


# Rapid loss of *Spartina patens*

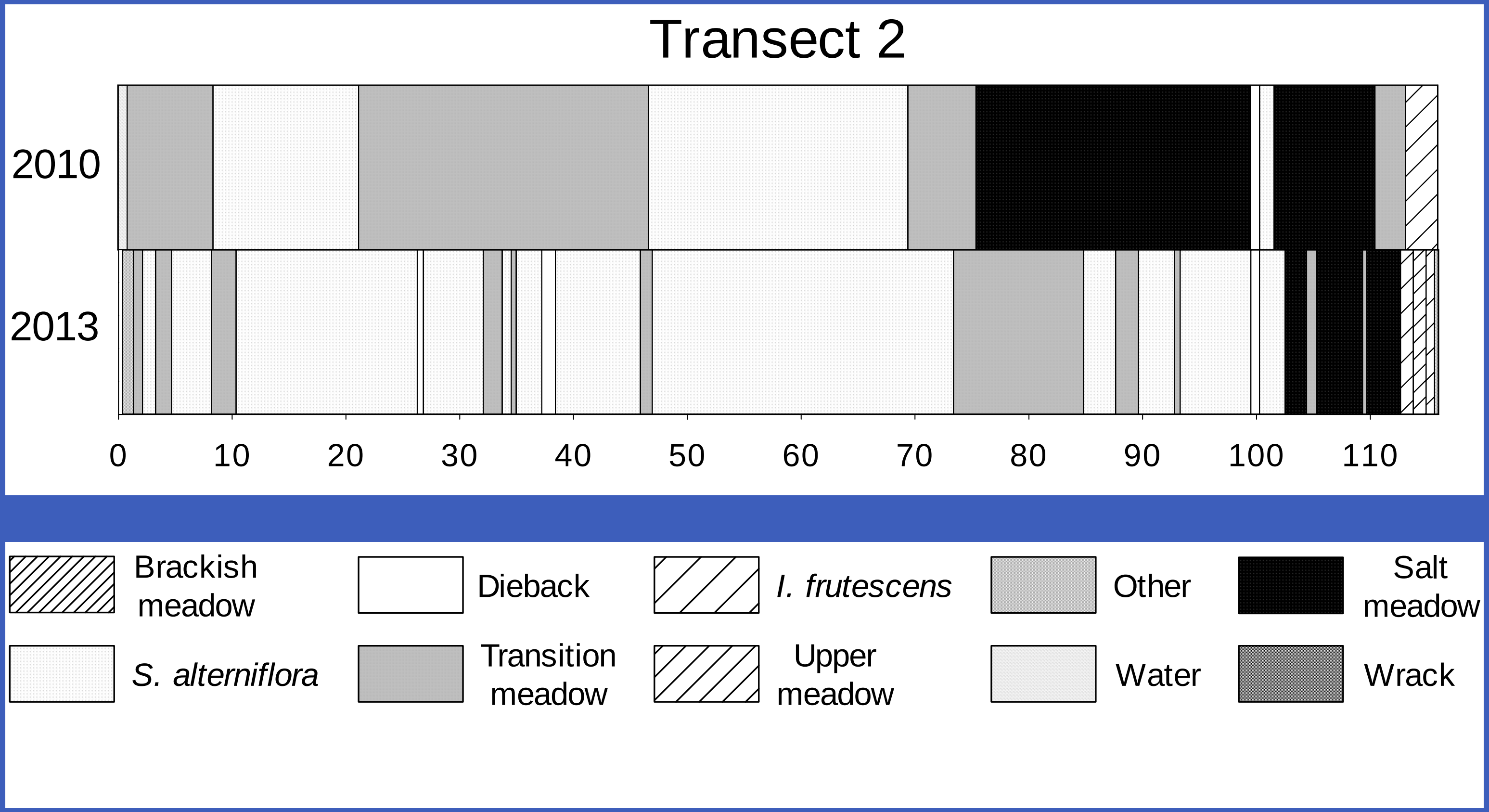
## Coggeshall Marsh




## Nag Marsh



# RTK Habitat Tracking



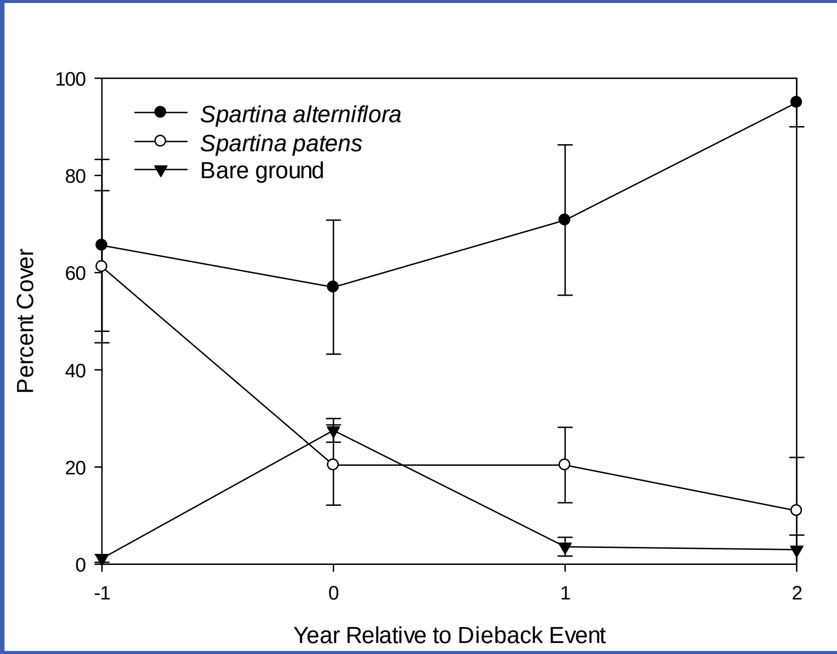
# Factors contributing to *S. patens* loss

- Marsh elevation (relative to NAVD88)
  - *S. patens* stable at 0.63 m
  - *S. patens* declining at 0.59 m
- Accretion rates
  - 2.7 mm $yr^{-1}$ from soil cores (Jo Carey soil cores);
- Sea level rise (Newport tide station)
  - 2.7 mm $yr^{-1}$ (1930-2012)
  - 7.5 mm $yr^{-1}$ (2000-2013)
- Dieback

# Vegetation dieback

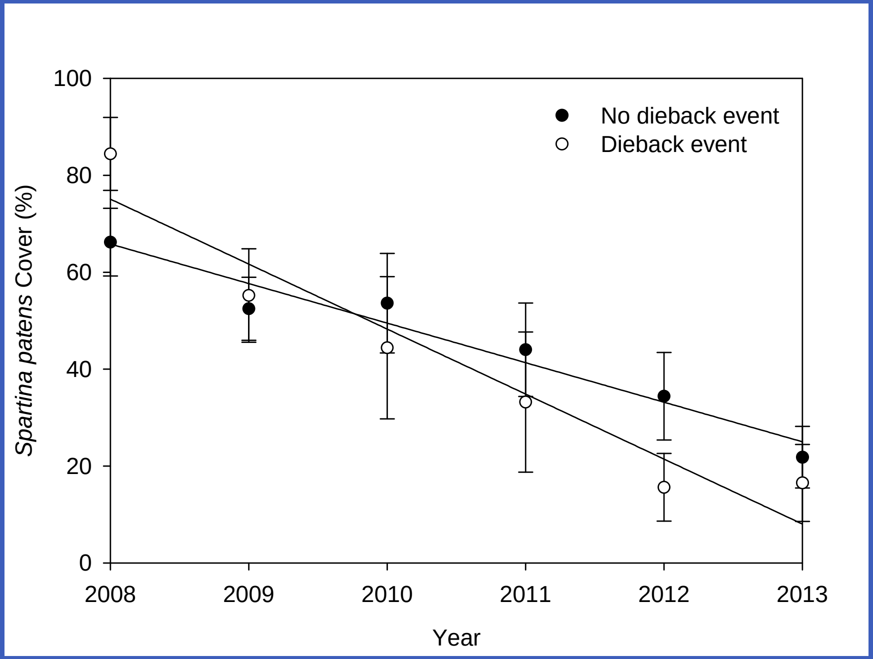
## Dieback occurring in Nag Marsh

## Species responses to dieback

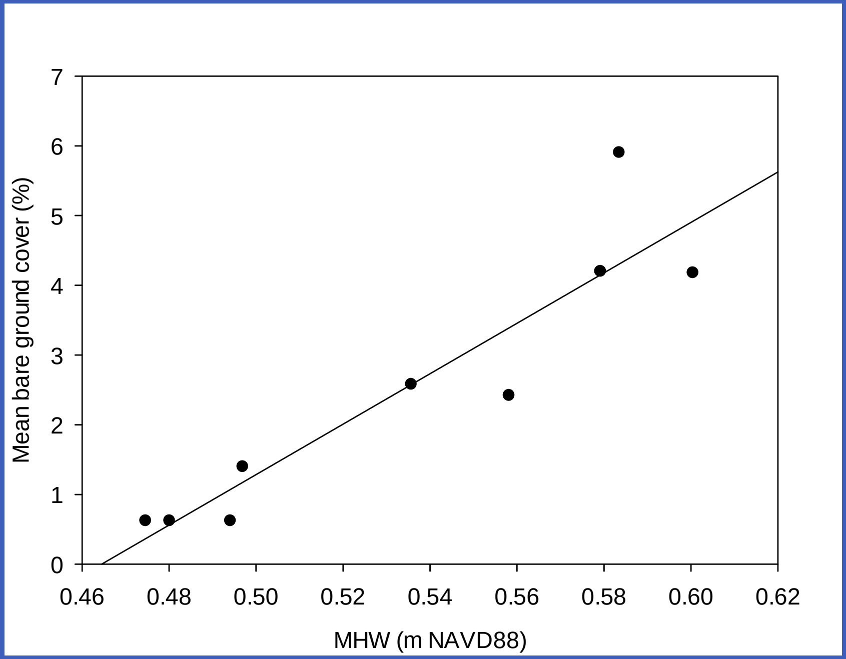


# Vegetation dieback, cont.

**Dieback accelerates loss of *S. patens***

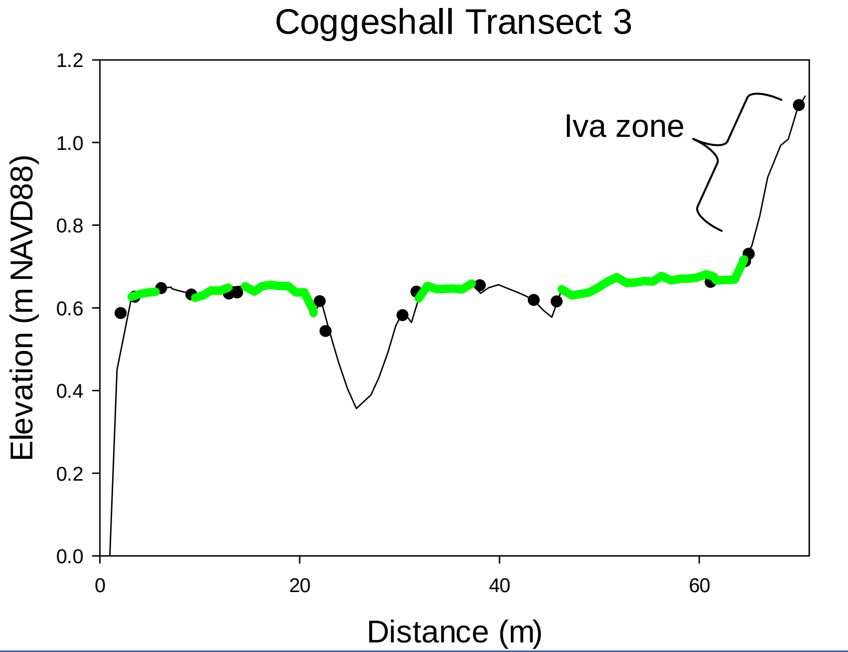


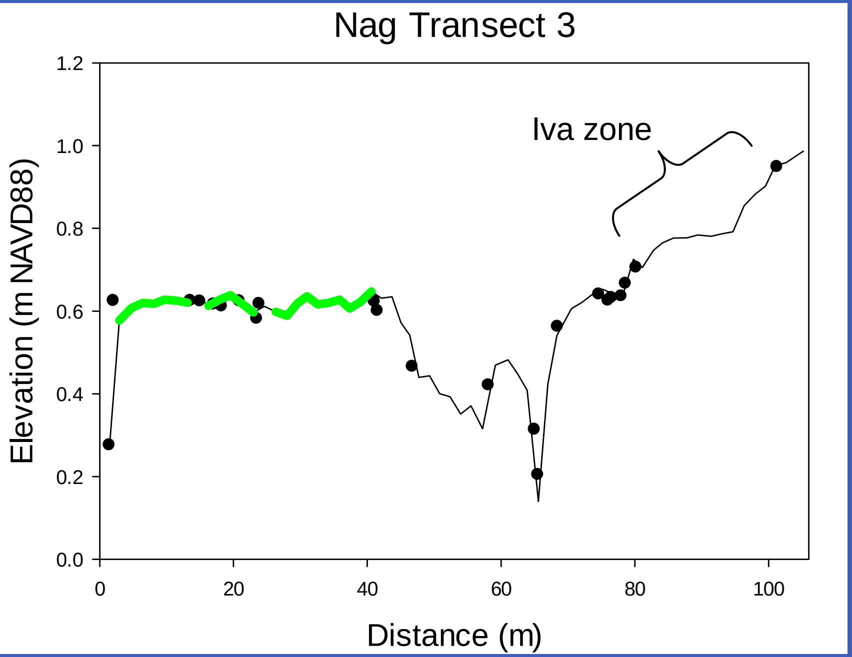

**Dieback related to MHW levels**



# Recovery of dieback areas

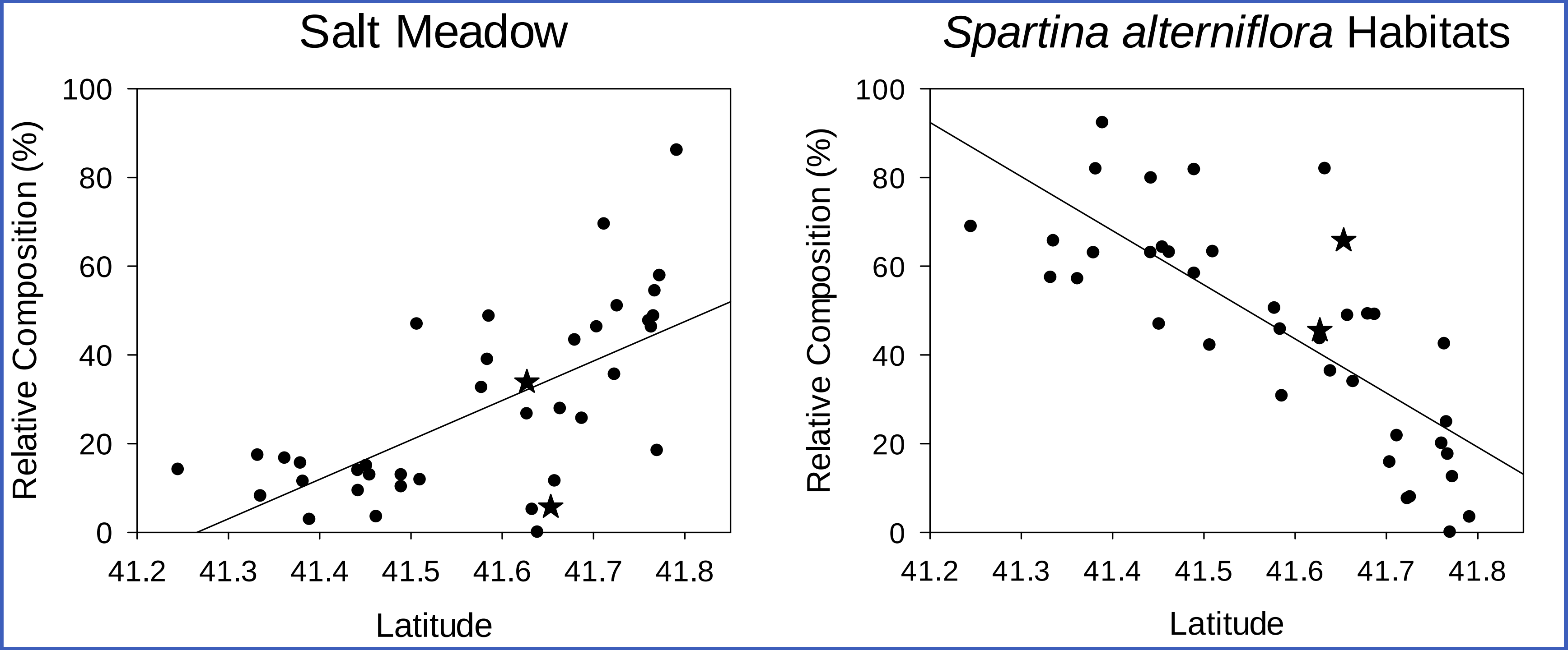
# High Marsh Transgression




* Over 140 years for high marsh to reach start of *Baccharis* zone

# Broad-scale patterns (RISMA)



# Summary and Next Steps

- Rapid decline in high marsh *Spartina patens*;
  - Steady loss at low elevations;
  - Sudden loss due to dieback;
  - Consistent with Warren and Niering (1993), Smith (2009);
  - Supports Donnelly and Bertness (2002);
- Automated classification and mapping of marsh habitats throughout RI.

# DEVELOPING A SALT MARSH ASSESSMENT FOCUSED ON THE IMPACTS OF RAPID SEA LEVEL RISE


Marci Cole Ekberg[1]

Wenley Ferguson[1]

Kenny Raposa[2]

[1] SAVE THE BAY® NARRAGANSETT BAY

[2] Narragansett Bay Research Reserve

# Introduction

- Conditions can change rapidly in tidally restricted marshes
- Degraded conditions have recently been found in marshes with no tidal restrictions
- Rapid sea level rise and higher than predicted tides could be major drivers of change


# State-wide assessment of Narragansett Bay and RI South Shore salt marshes: 2012-2013

Goals of RISMA:
- Establish baseline marsh condition
- Monitor changes over time of vegetation communities
- Identify adaptive management opportunities

# Methods

Three Tier Approach

Tier 1: GIS based, landscape scale assessment

Tier 2: Field based rapid assessment

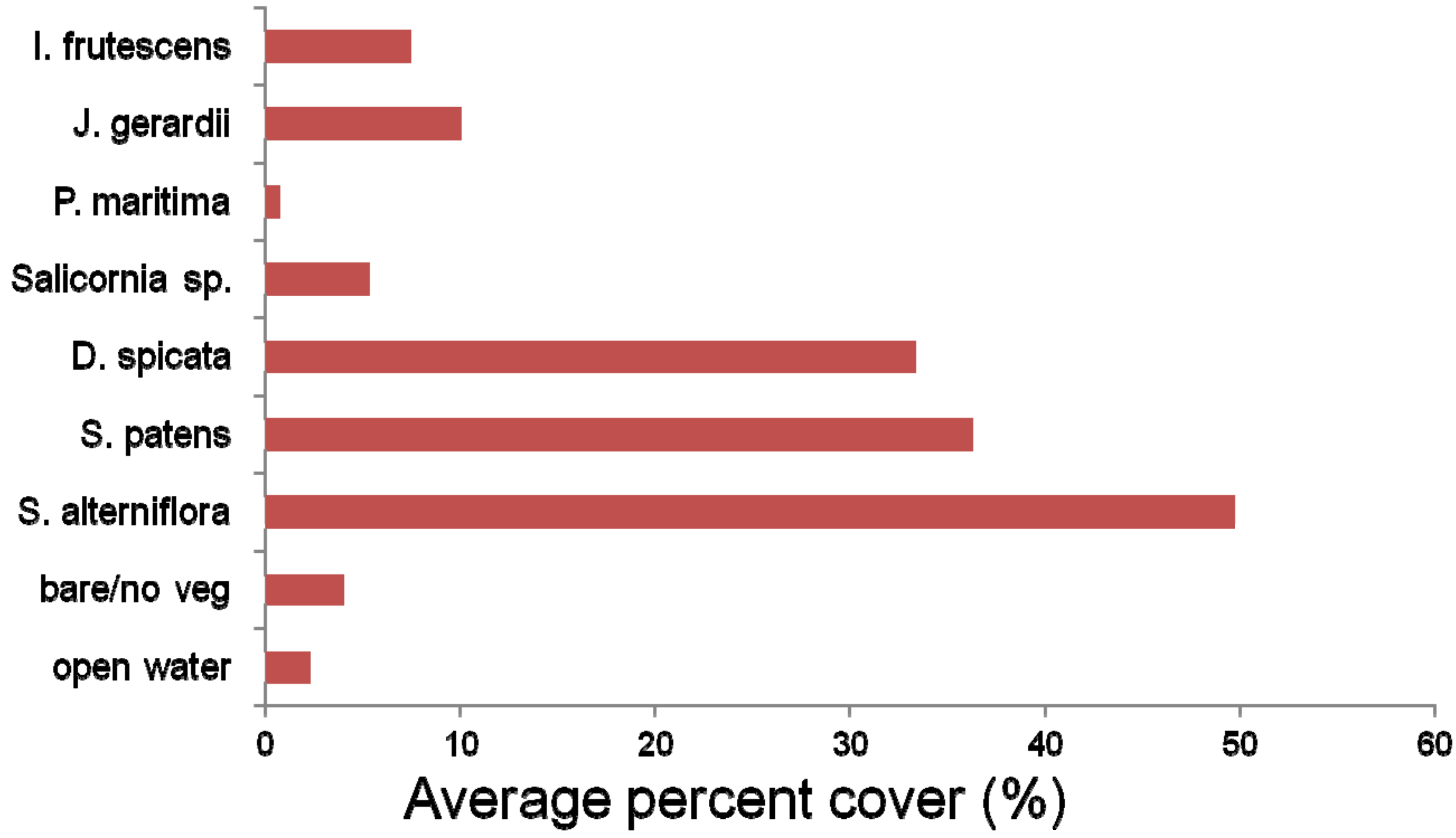
•Point intercept/*S. alterniflora* height

•Marsh communities

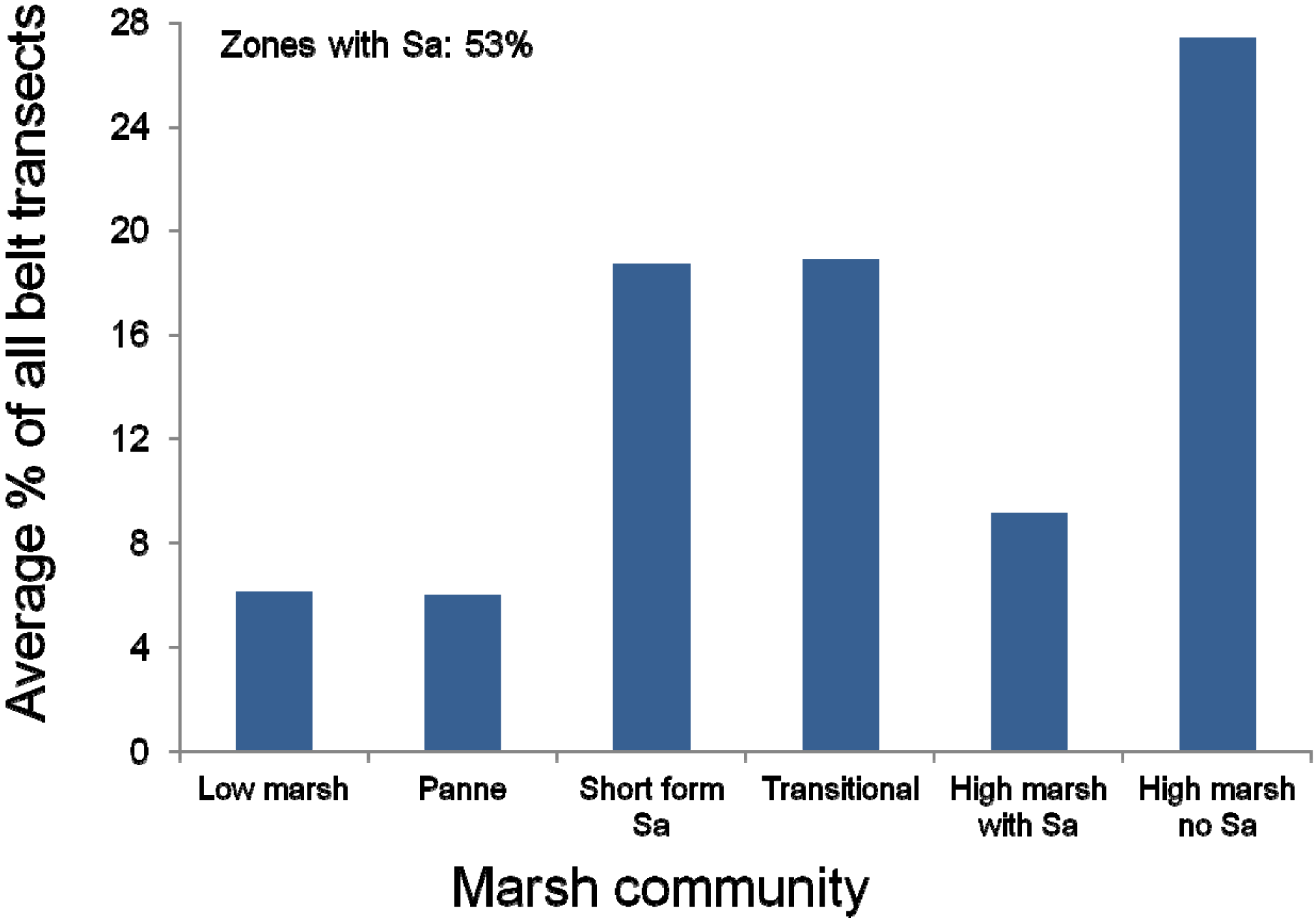
•Bearing capacity

Tier 3: Series of intensive, research based studies

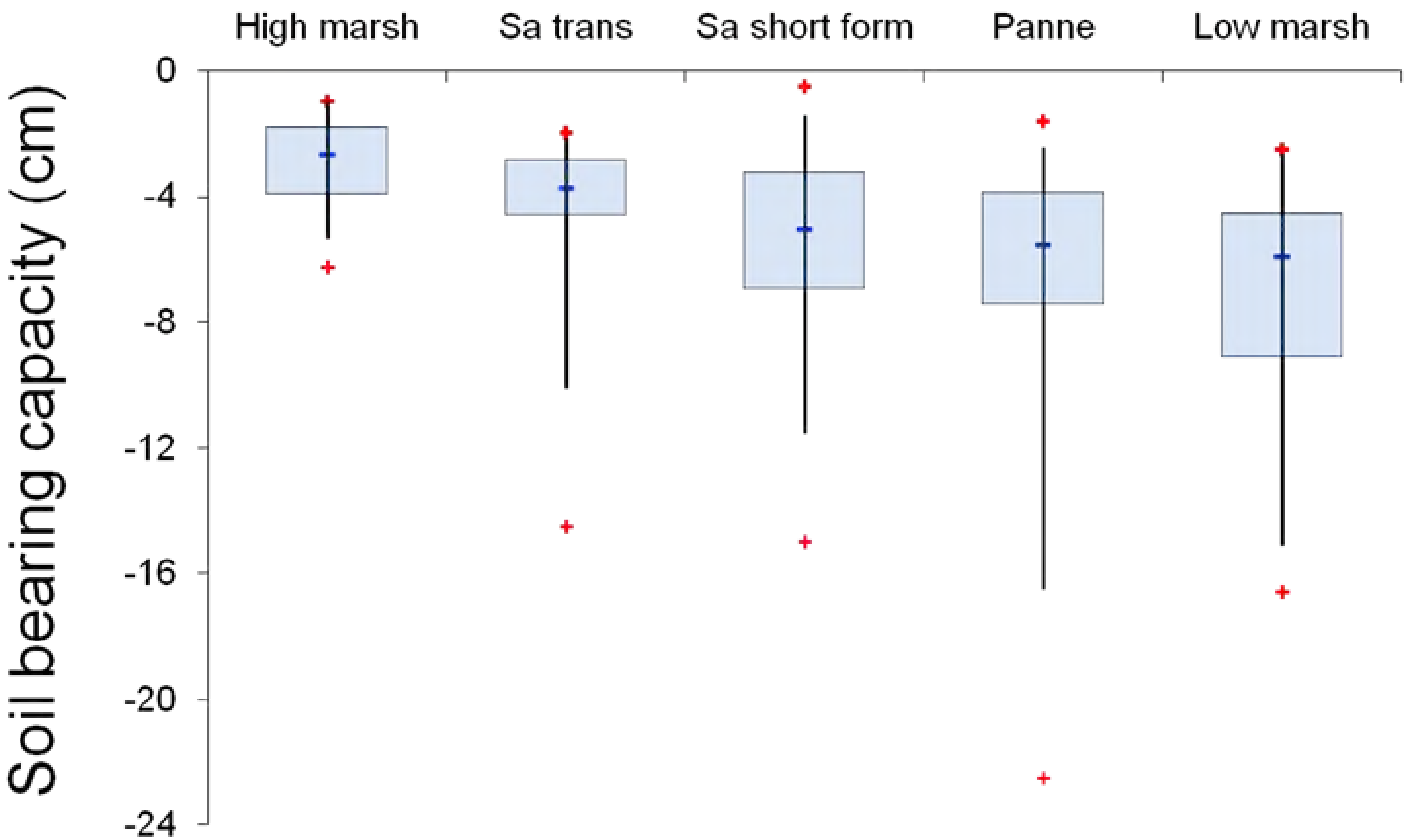
# Point Intercept Results



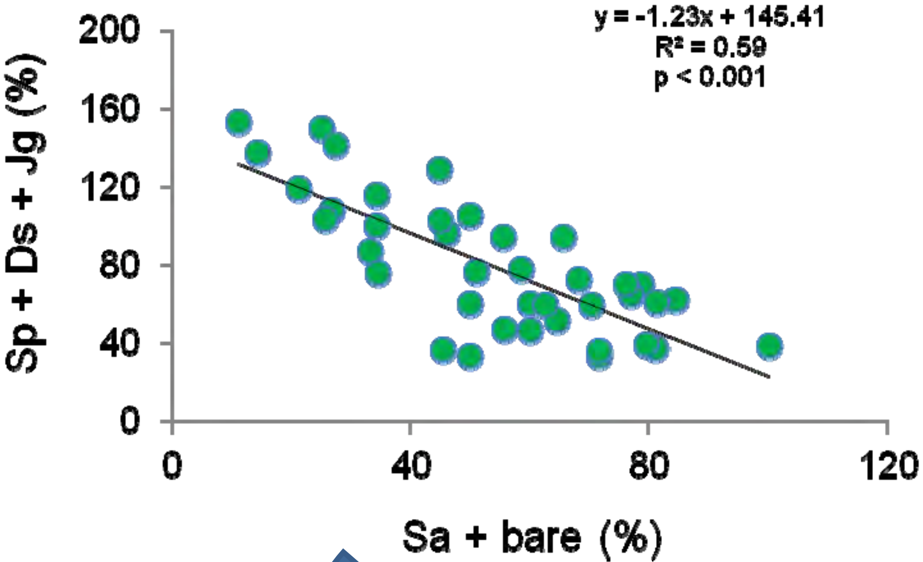
# Marsh Community Results

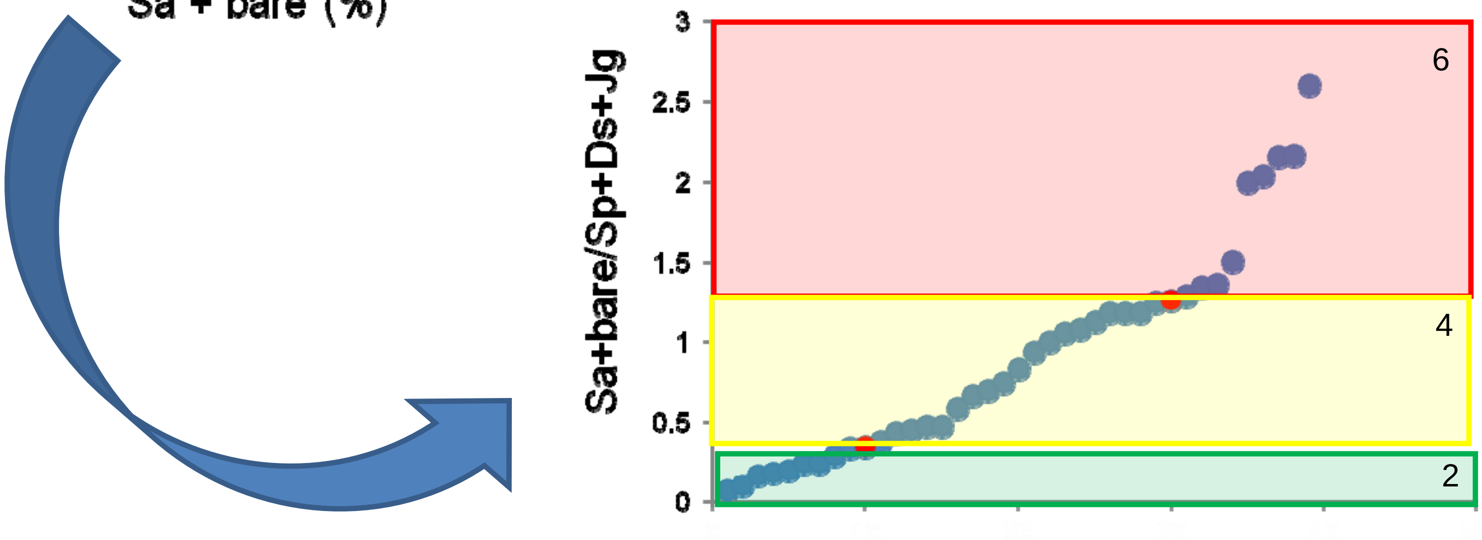


# Bearing Capacity Results



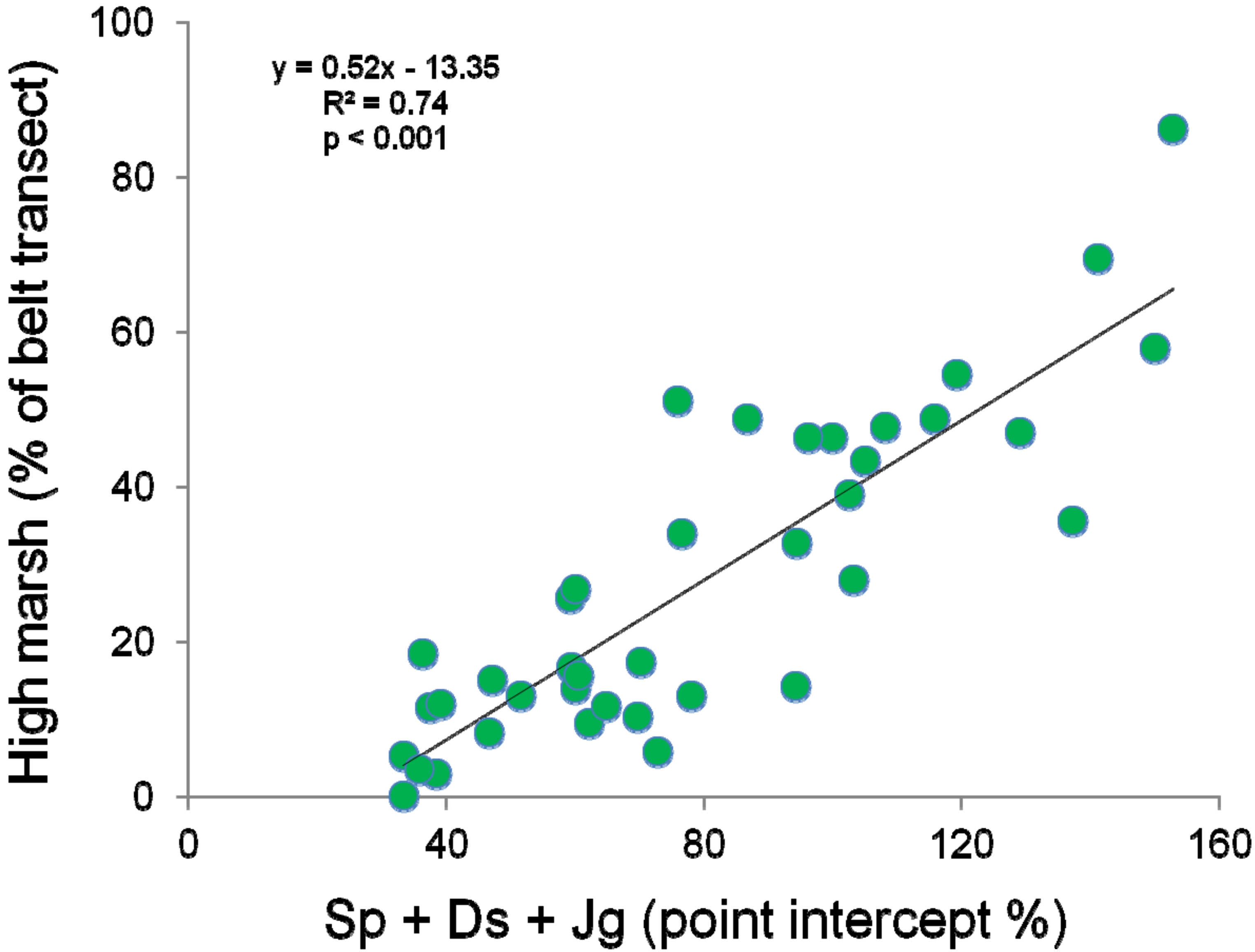
# Using Results to Develop Ranks



# Using Results to Identify Priorities

# Reassessing Methods



# Next steps

- Develop state wide salt marsh monitoring strategy
- Finish GIS analysis
- Conduct RISMA at additional sites
- Finalize ranking system and identify priority sites to monitor and "restore"
- Share data with resource managers

# Future Questions

- Can we adapt this protocol to use across a broader geographic area?
- What should the monitoring interval be?
- Should parameters be included (nekton, birds, soil pH) or removed?

# Thank You

CRMC
COASTAL RESOURCES MANAGEMENT COUNCIL

U.S. Fish & Wildlife Service

Coastal Program

# A GIS Assessment of Salt Marsh Change in RI from 1981 to 2008

Meghan Nightingale
Wild & Scenic
401-497-9954
Meg.gallagher@pobox.com

# Background

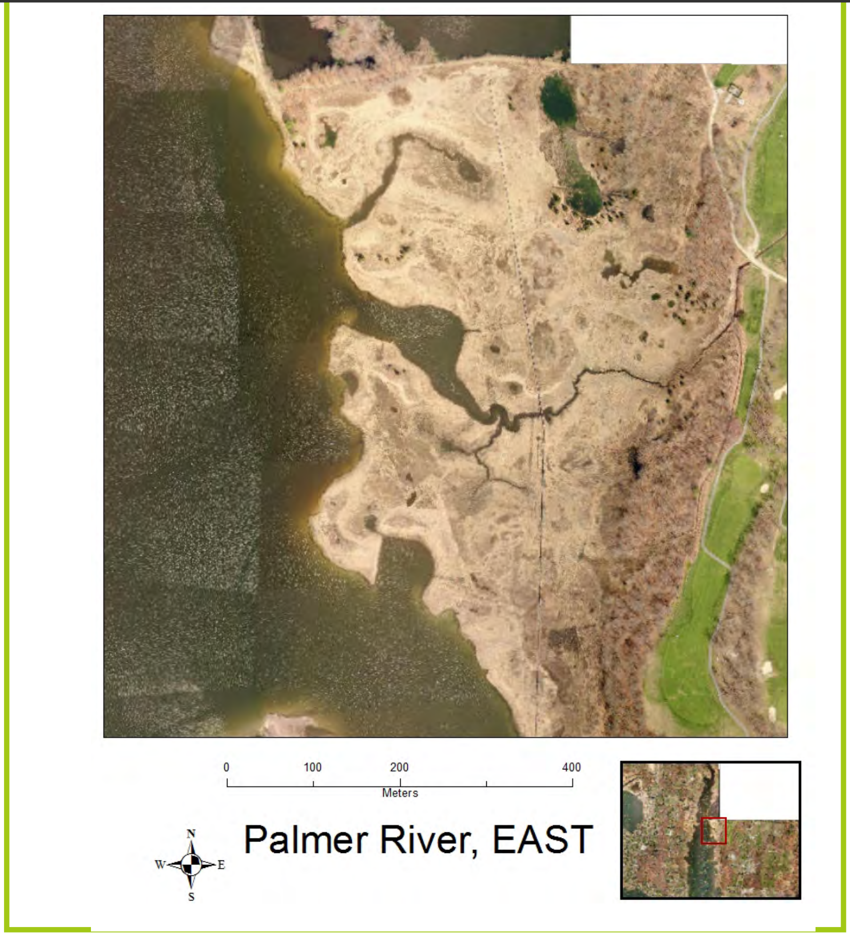
- The population of Seaside Sparrows decreased by half within 25 years.

- Utilized a multifunctional assessment model to determine habitat quality of Salt marshes.

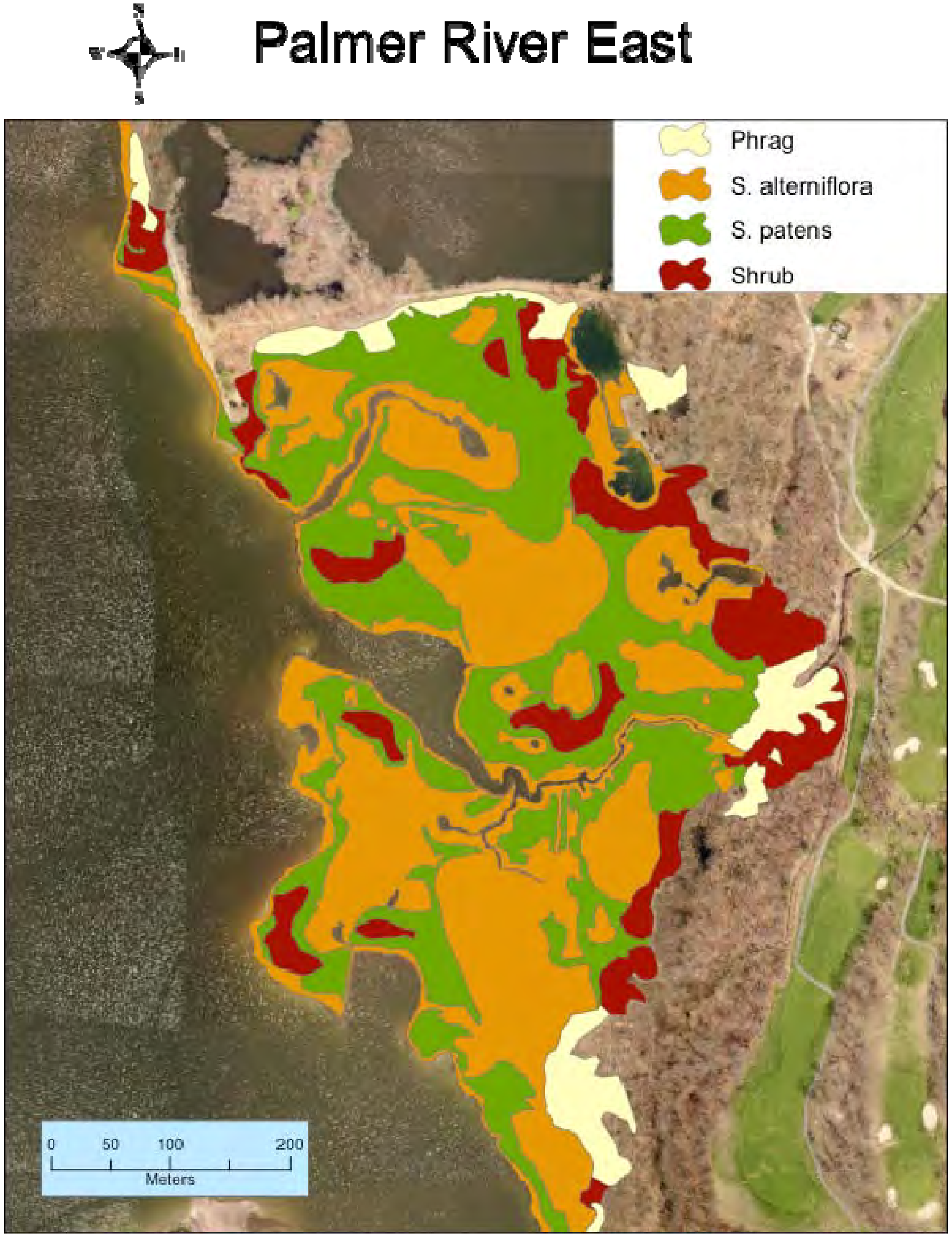
# Methods

- Preliminary maps
  - 2008 aerial photography

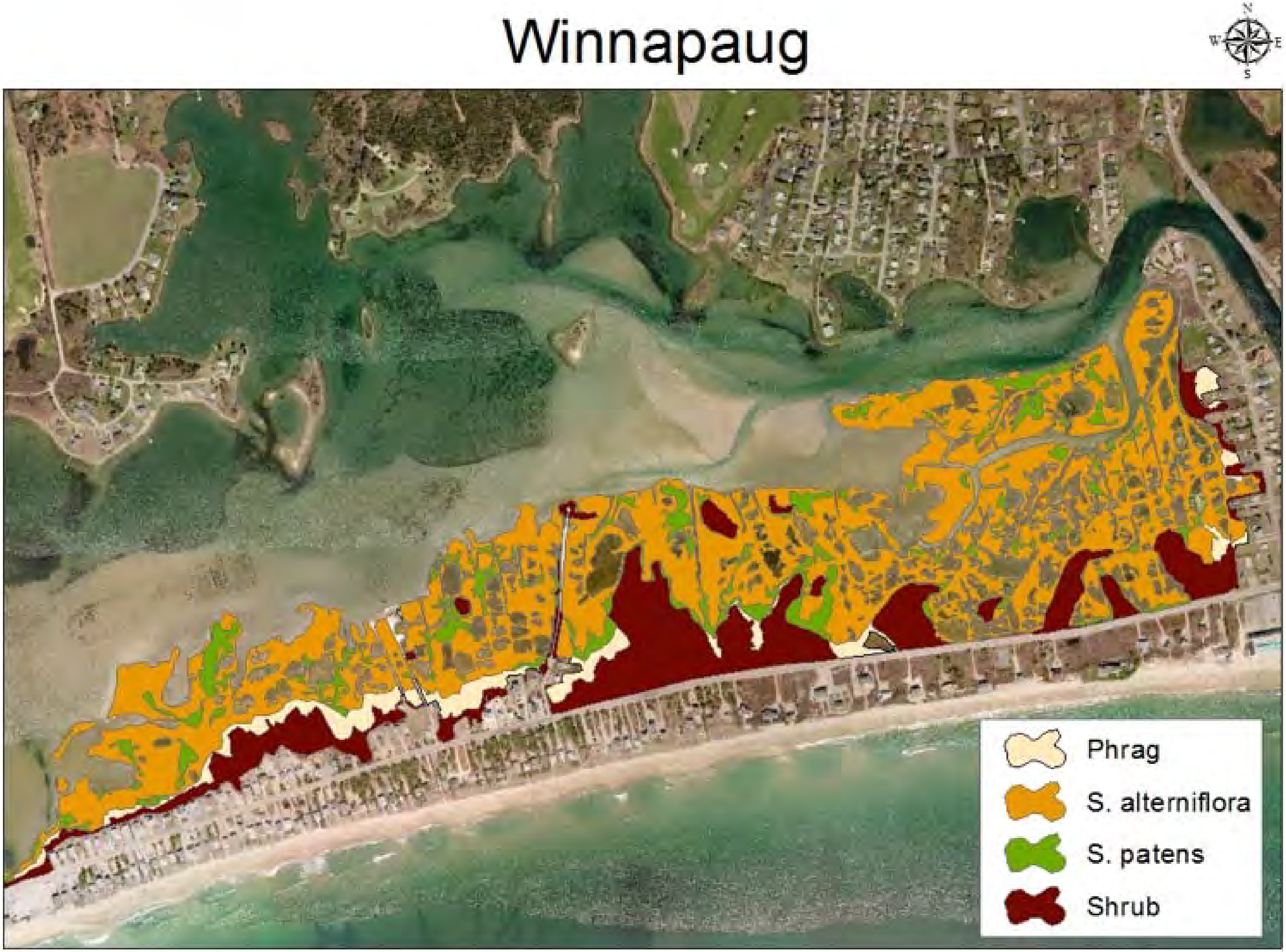
- Field work
  - Ground truth 20 sites



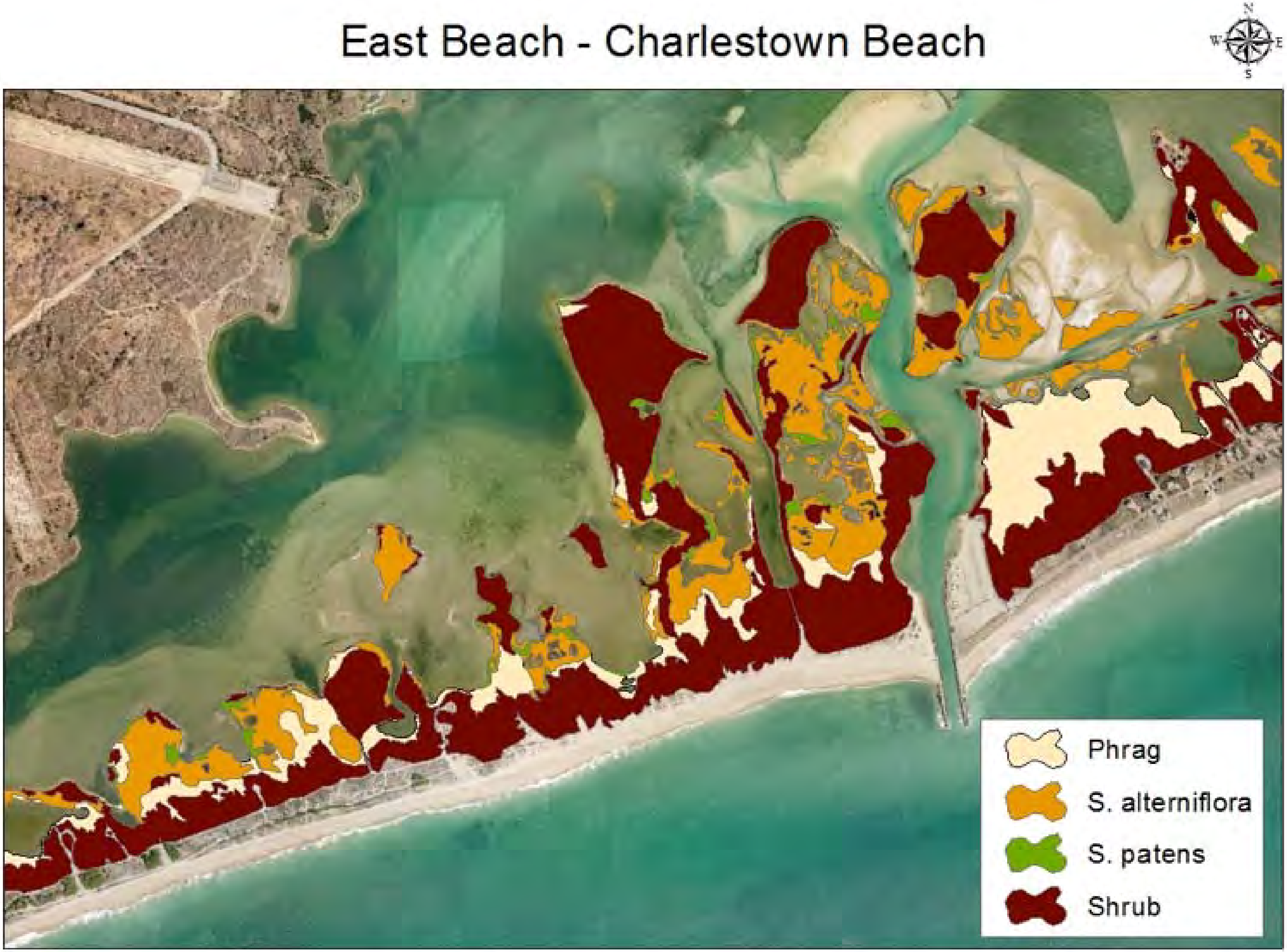
# Palmer River East



# Winnapaug



# East Beach - Charlestown Beach



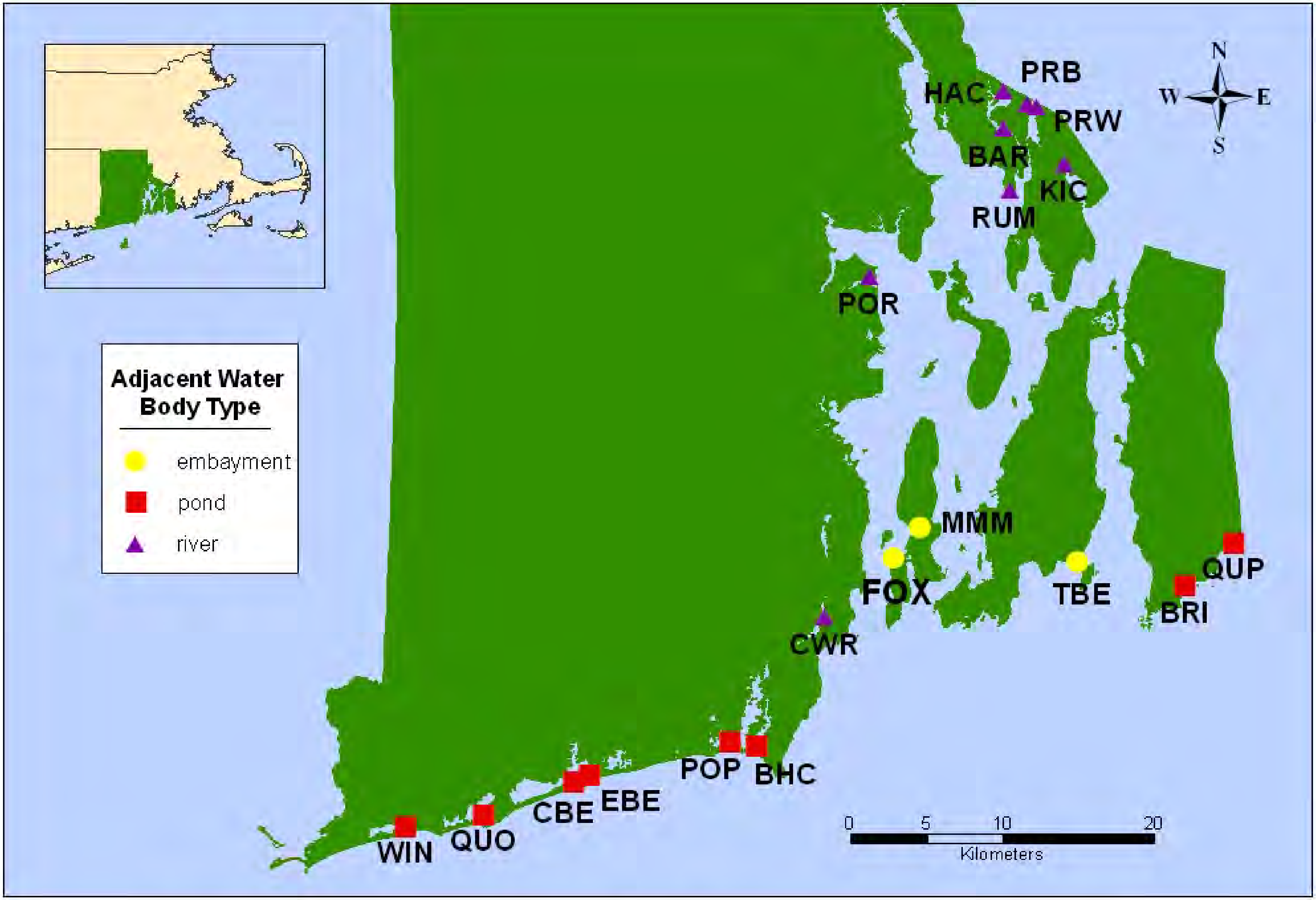



Figure 1. Location of salt marsh sites surveyed in 2007 in Rhode Island for breeding Seaside Sparrows.


© Doug Wechsler


© Doug Wechsler


© Doug Wechsler

???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© Doug Wechsler

# Methods

- Compared aerial photos from 1981 and 2008 by digitizing the marsh perimeter to calculate marsh change over time.


# Methods

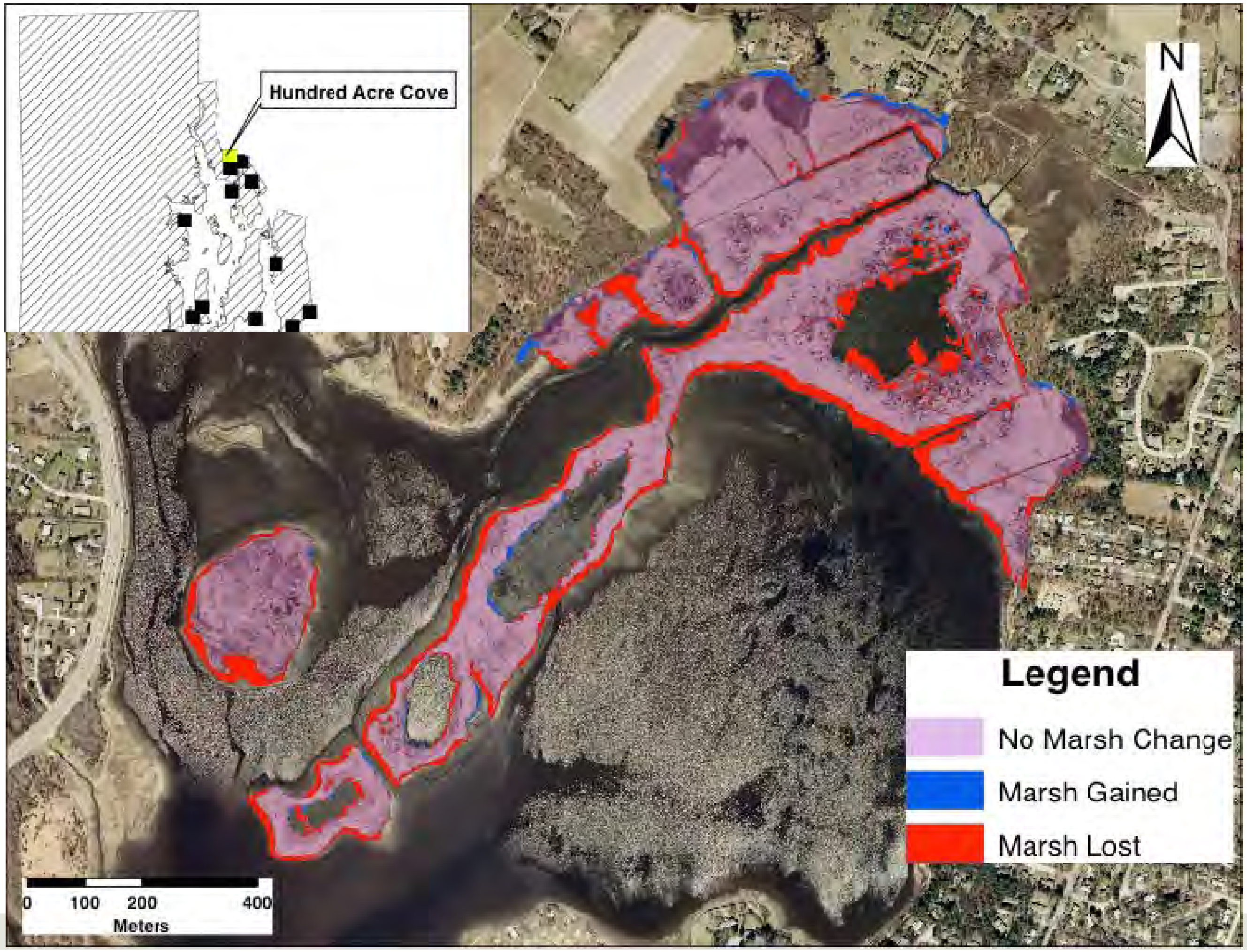
- Utilized the RIGIS E-911structures dataset to quantify changes in residential development.
  - 150m buffer
  - 1km buffer

# Results

- Salt marsh area decreased an average of 10%.
- Within 150m buffer – 71% increase in development.
- Within 1km buffer – 65% increase in development.

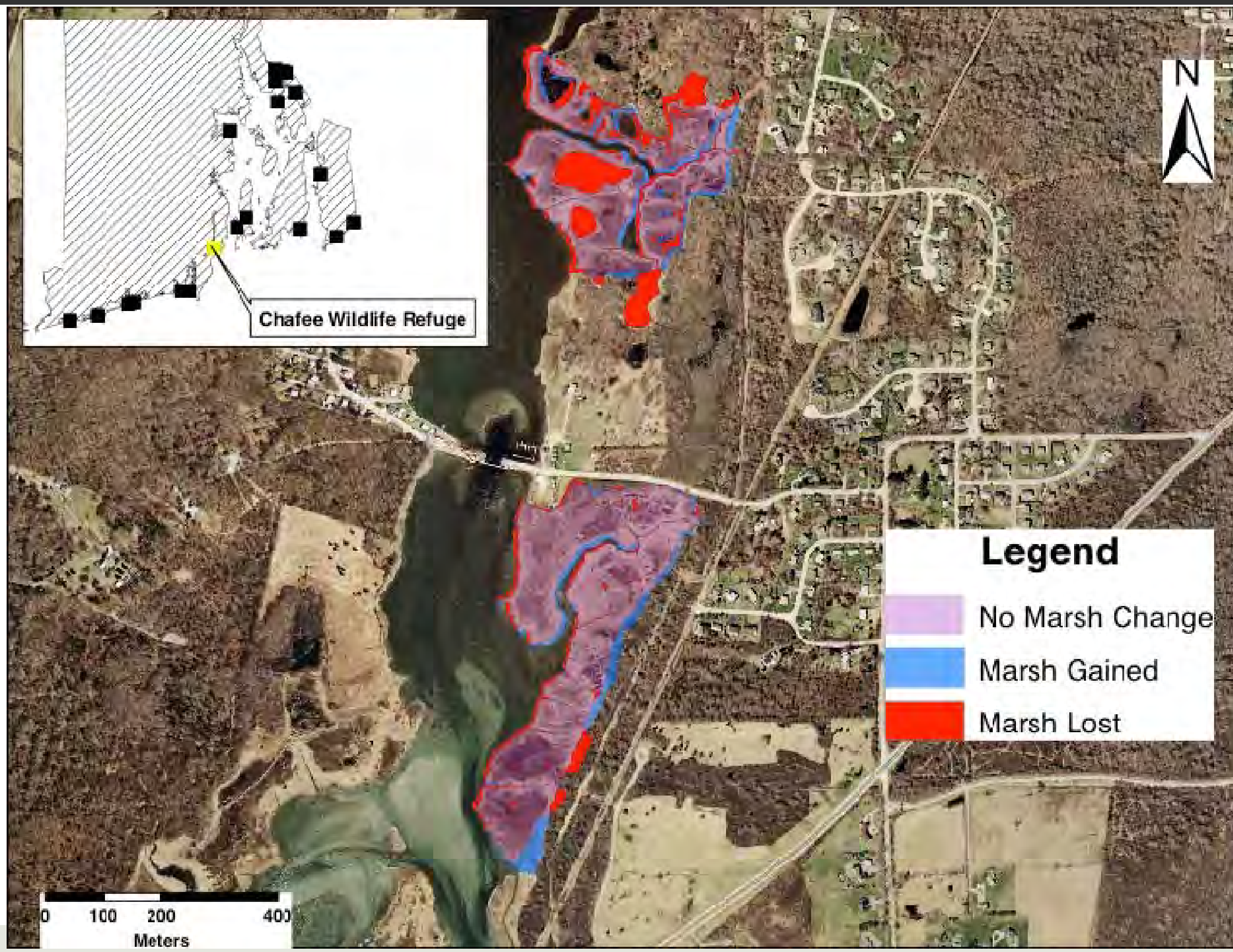
# 100 Acre Cove

Marsh Habitat – 20% Decrease
Development – 166% Increase



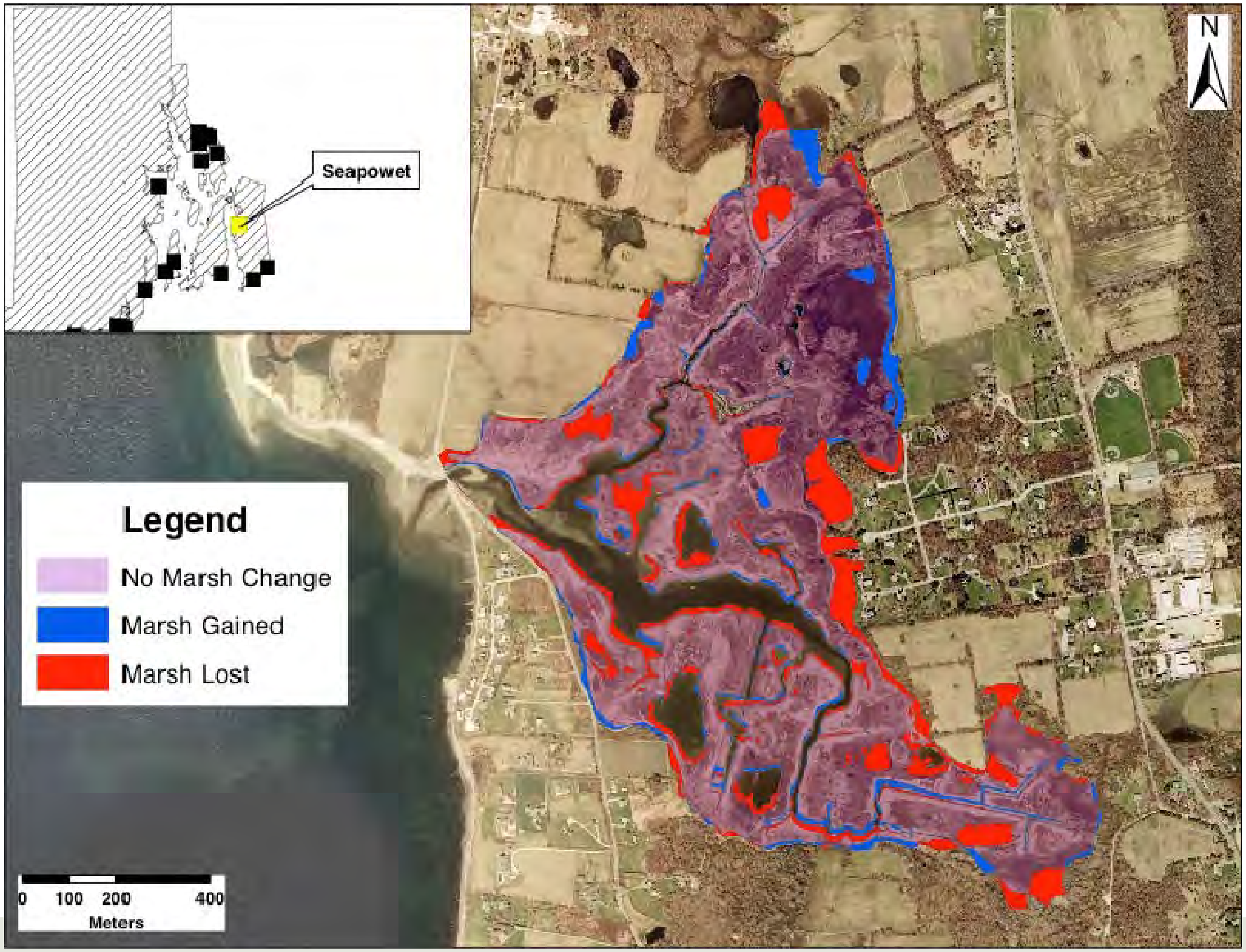
# Chafee WR

Marsh Habitat – 3% Decrease
Development – 80% Increase



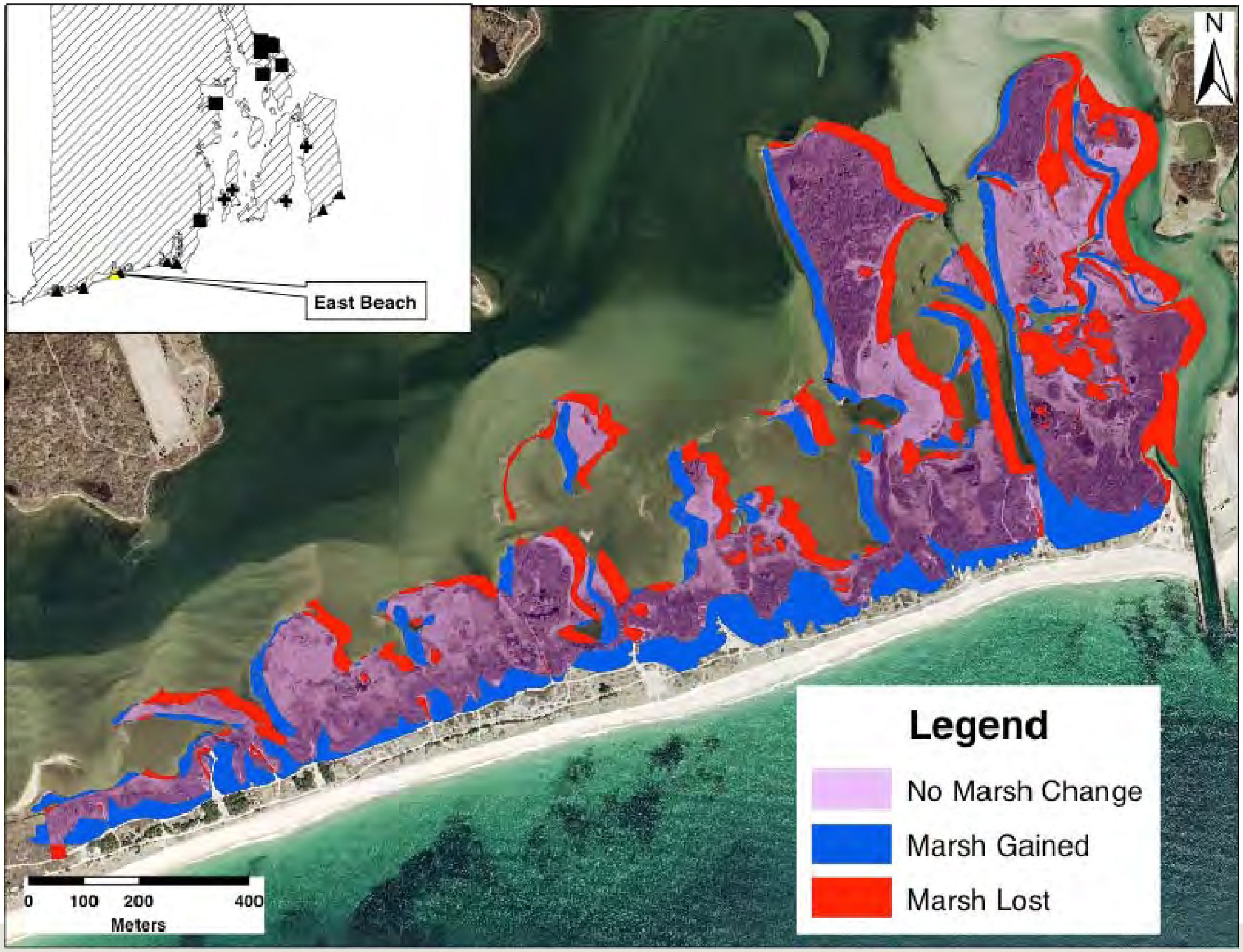
# Seapowet

Marsh Habitat – 13% Decrease
Development – 53% Increase



# East Beach

Marsh Habitat – 14% Decrease
Development – No Change



# Marsh Loss Relative to Adjacent Water Body

- All of the marsh sites lost habitat
- Marshes adjacent to:
  - Coastal Ponds lost an average of 18%
  - Rivers lost an average of 6%
  - Embayments lost an average of 7.4%

# Conclusions

There is no significant correlation between the land use/cover data with the change in sparrow population.

There was also no significant correlation between the increase in development and loss of marsh habitat.

# Phragmites

Increased development can cause increased areas of *Phragmites* on a salt marsh.

*Phragmites* was not visible enough on many of the historical photos to delineate with confidence.

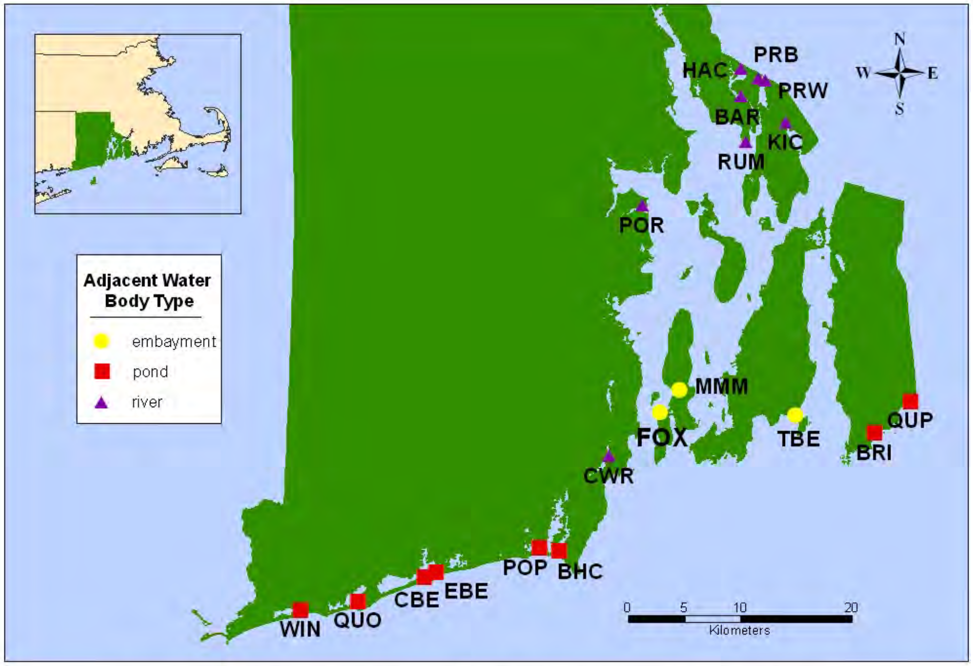
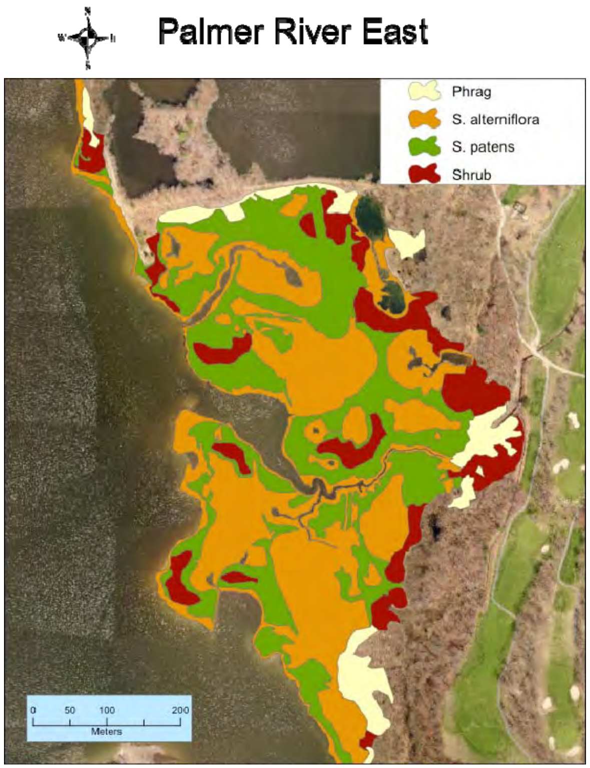



Figure 1. Location of salt marsh sites surveyed in 2007 in Rhode Island for breeding Seaside Sparrows.




Find the Shapefiles at:

http://www.edc.uri.edu/mesm/Docs/MajorPapers/MN/default.htm


Contact:

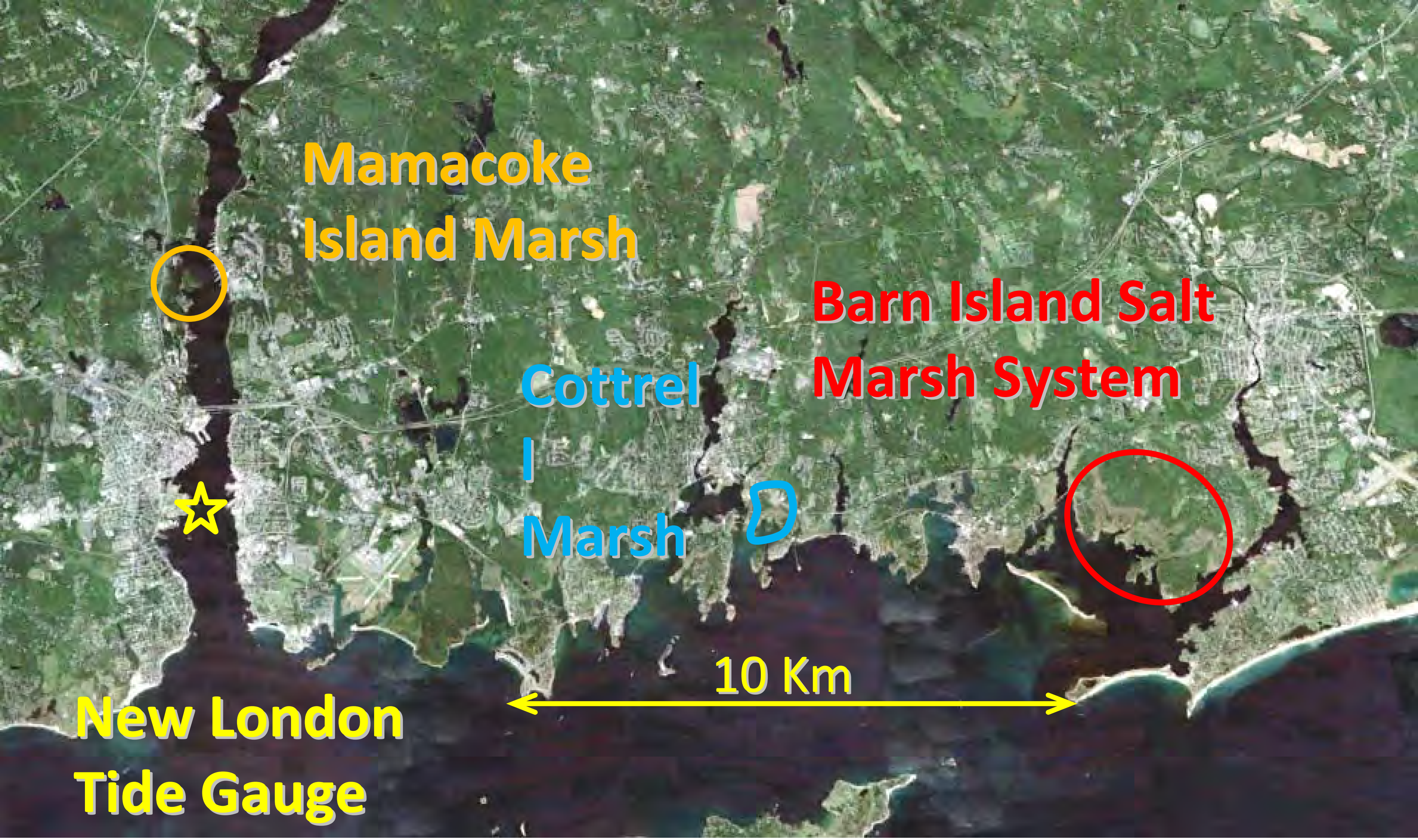
Meg.gallagher@pobox.com

401-497-9954

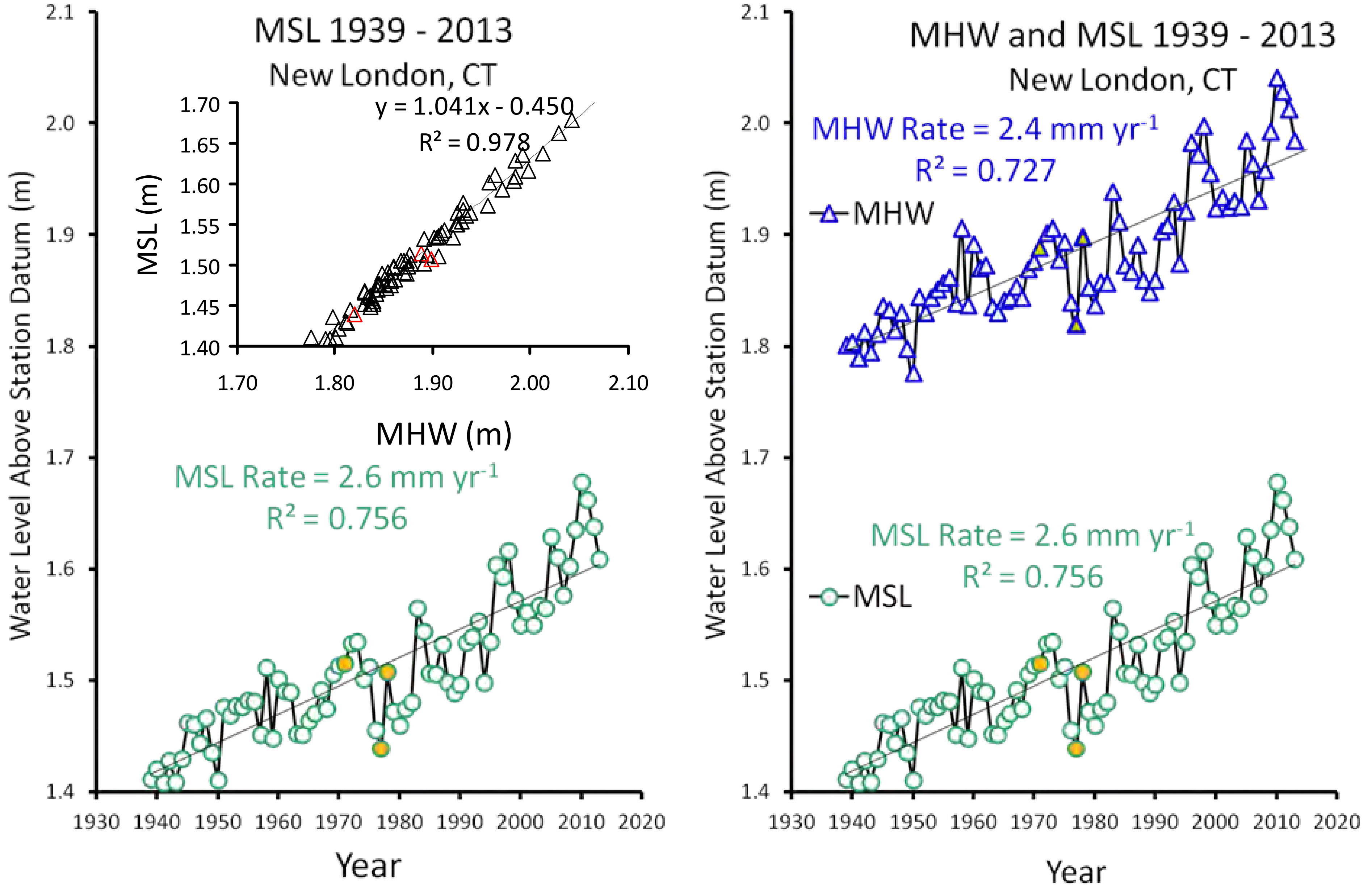
# Salt Marshes and Sea Levels in Eastern Long Island Sound


Scott Warren

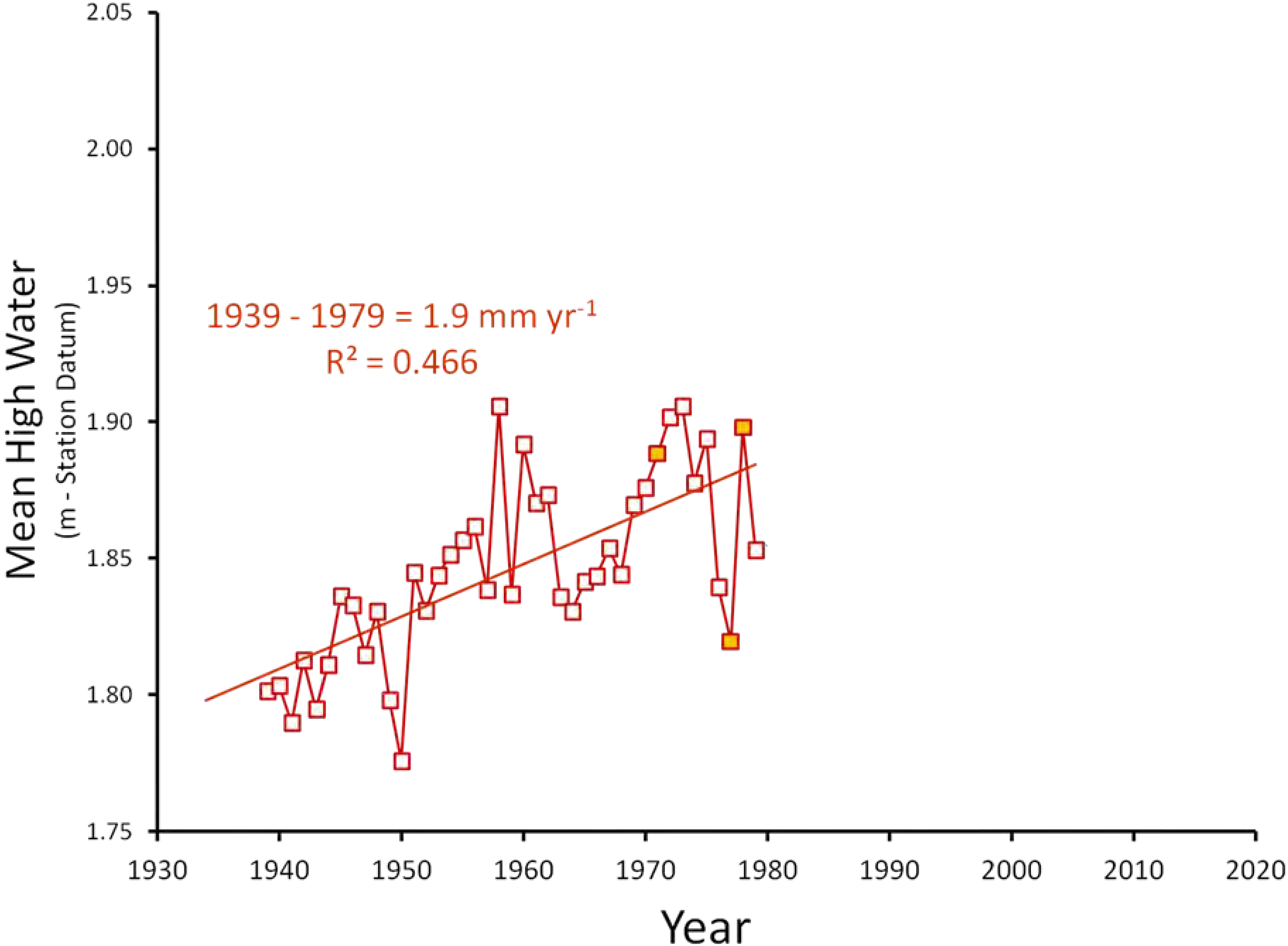
Happily Retired

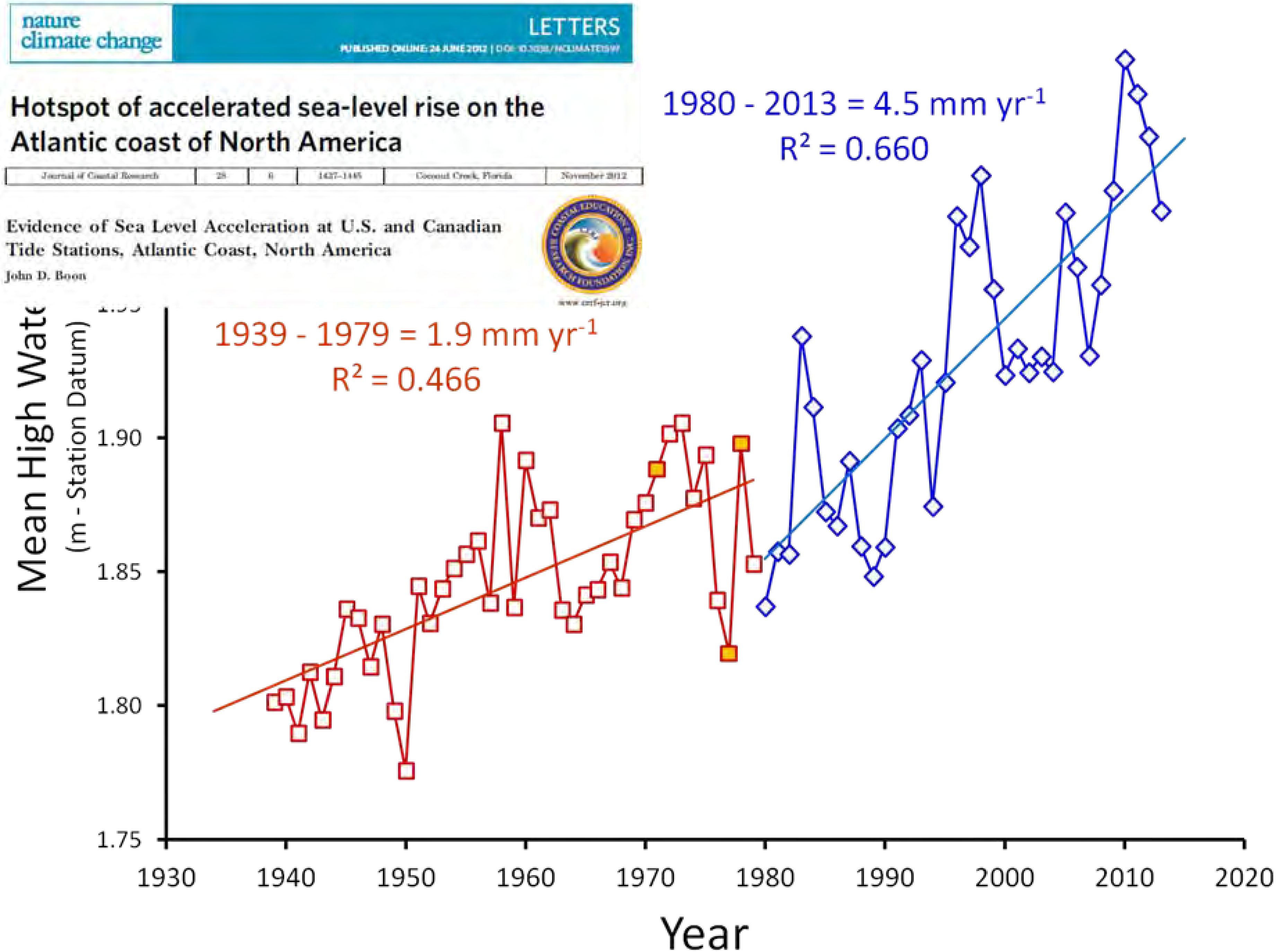




# Major Players in this Presentation

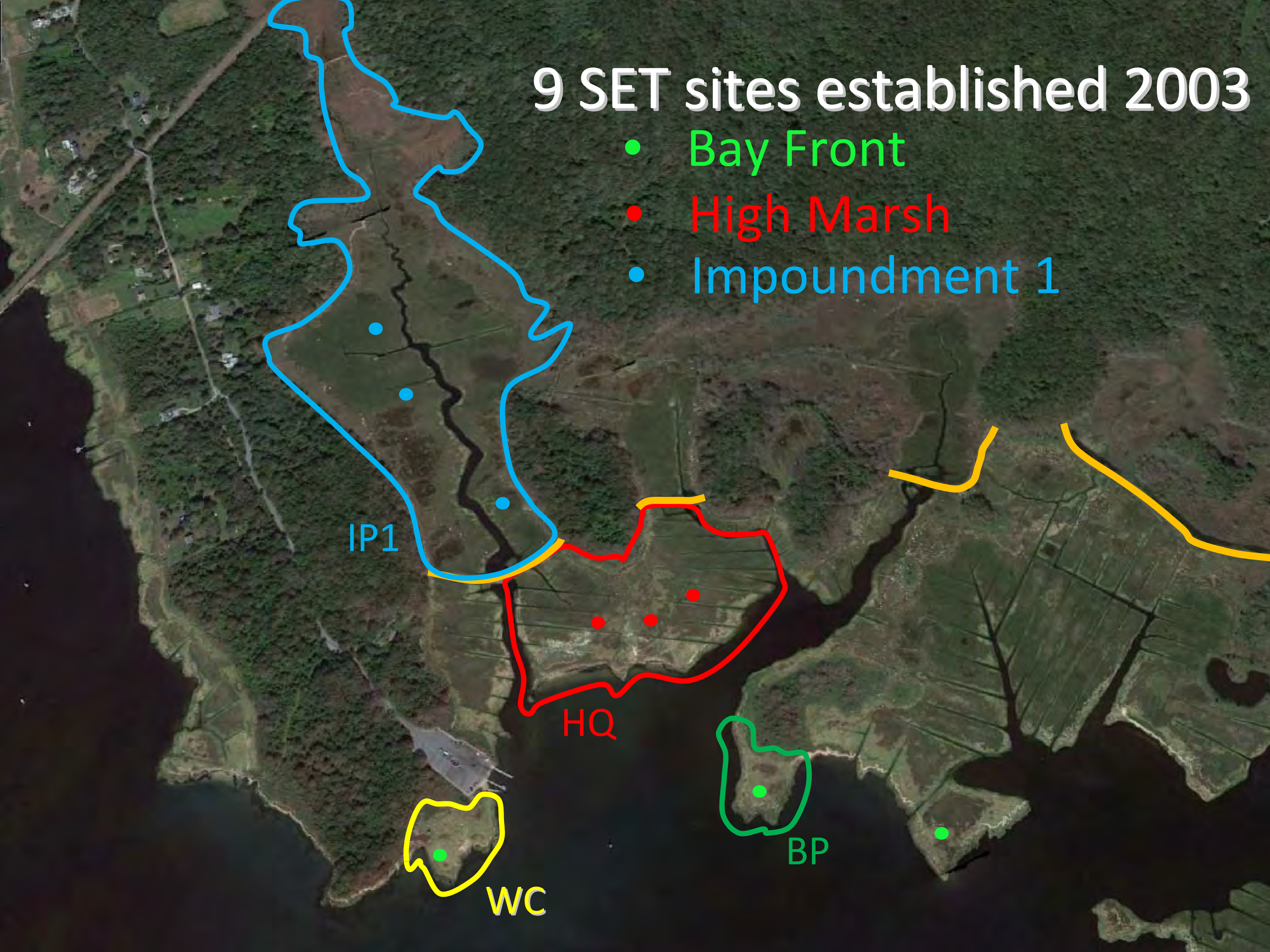



# New London Tide Gauge Record: Annual Means 1939 - 2013

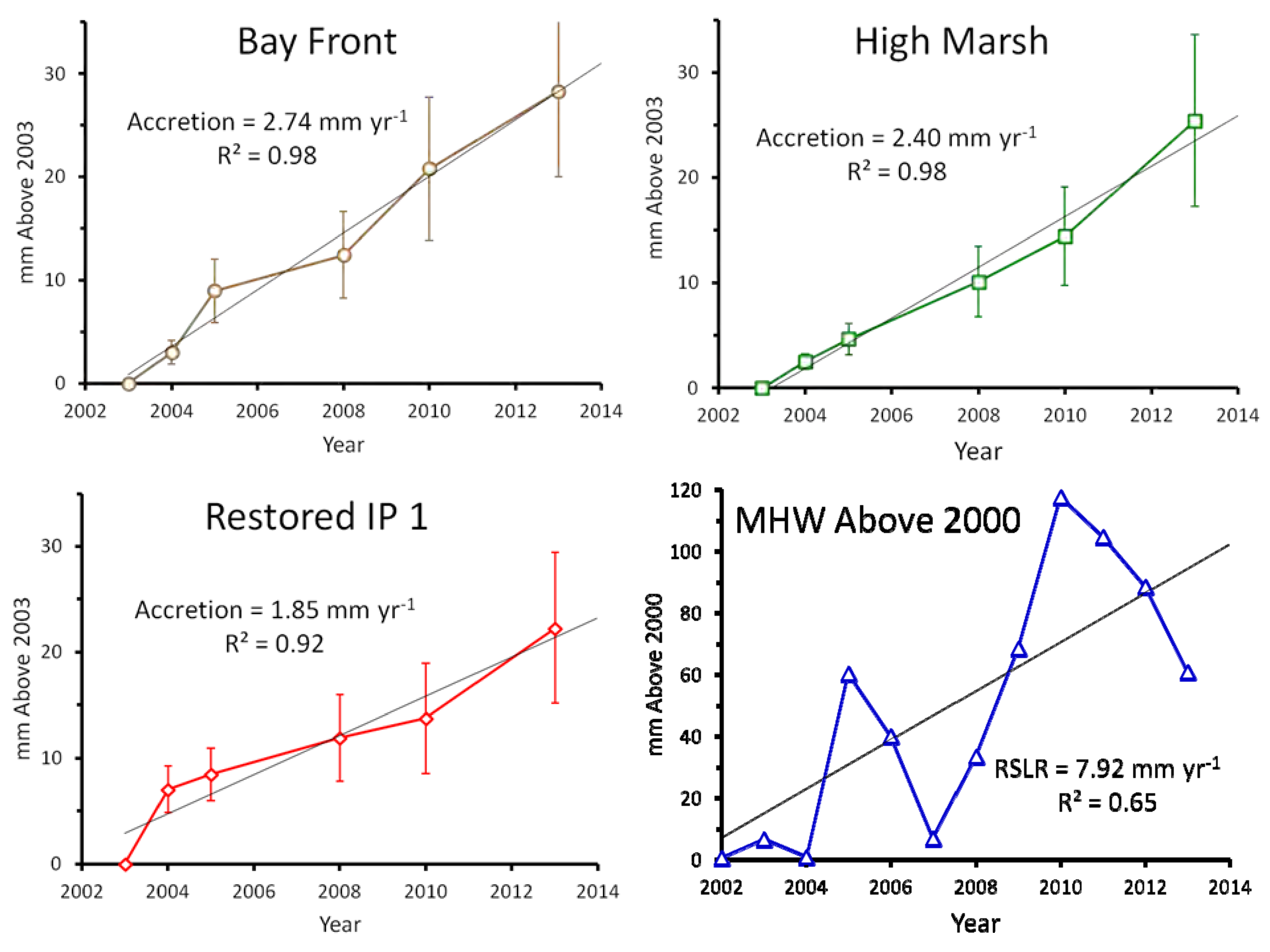

1939 - 1979 = 1.9 mm yr-1
R2 = 0.466
Mean High Water
(m - Station Datum)
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

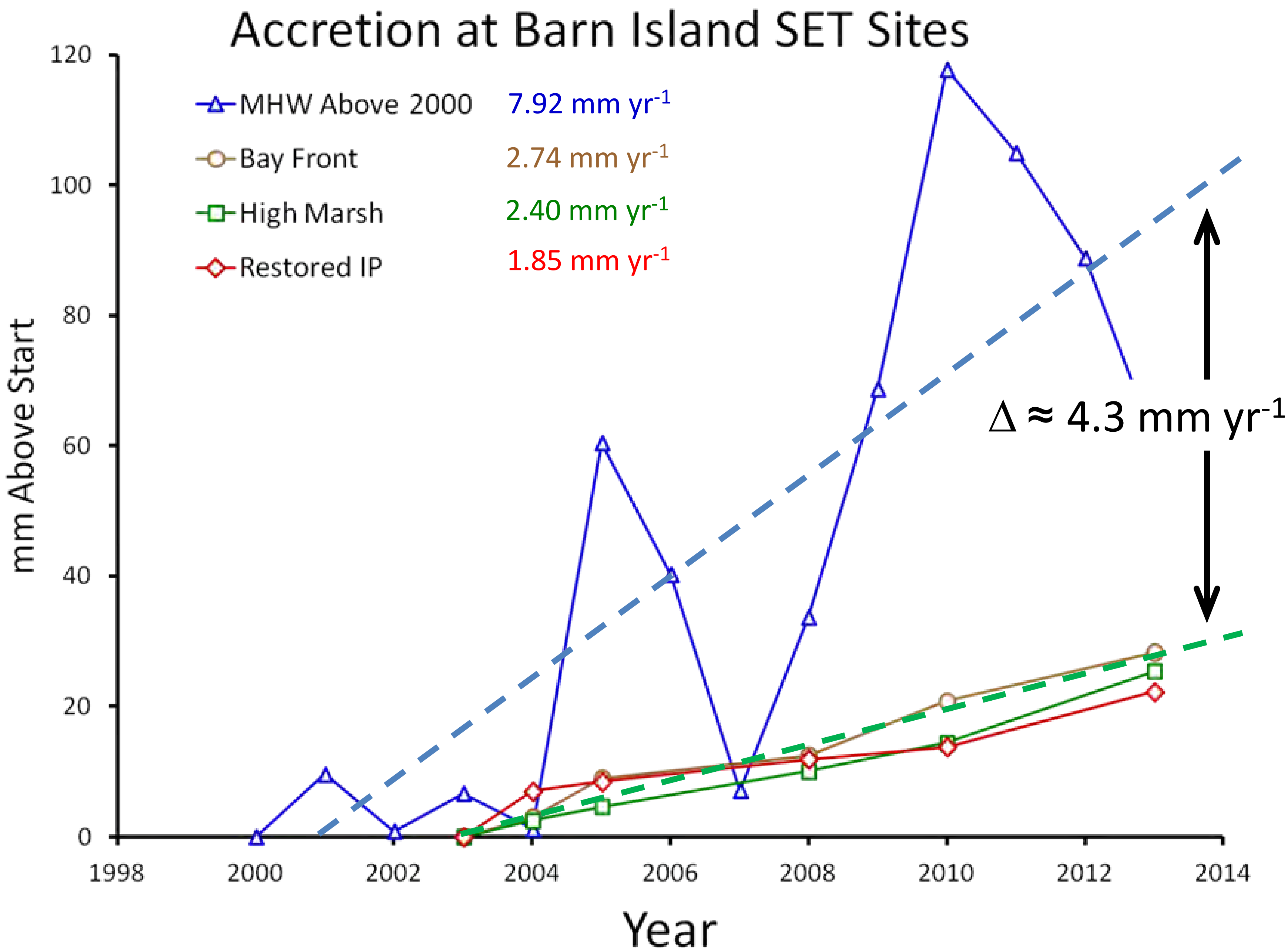

nature climate change
LETTERS
Hotspot of accelerated sea-level rise on the Atlantic coast of North America
Journal of Coastal Research
Coconut Creek, Florida
November 2012
Evidence of Sea Level Acceleration at U.S. and Canadian Tide Stations, Atlantic Coast, North America
John D. Boon
1980 - 2013 = 4.5 mm yr-1
R2 = 0.660
1939 - 1979 = 1.9 mm yr-1
R2 = 0.466
Mean High Wate
(m - Station Datum)
1.90
1.85
1.80
1.75
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

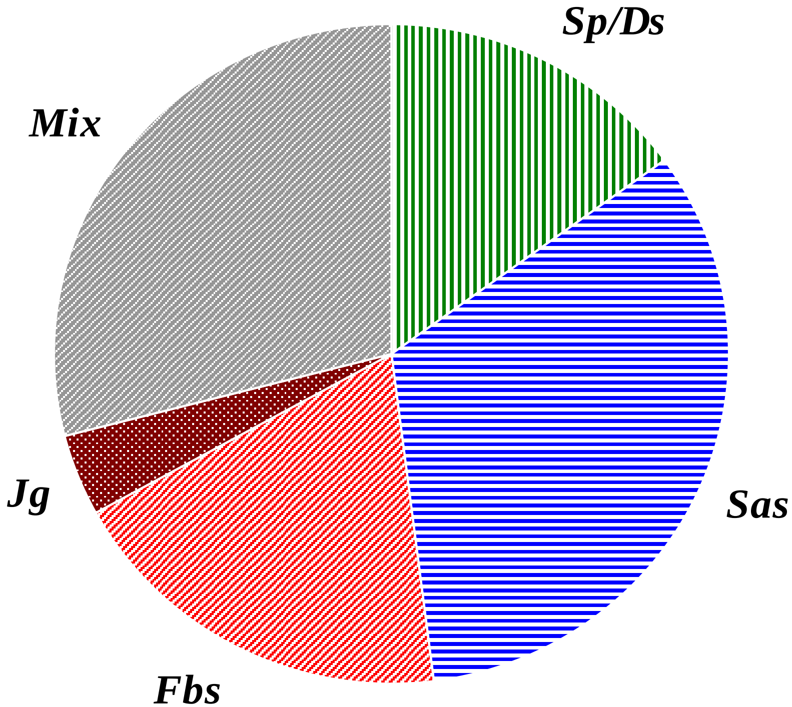

The Barn Island Salt Marshes
Wequetequock Cove
Pawcatuck River
Sandy Point
Little Narragansett Bay
Napatree Point



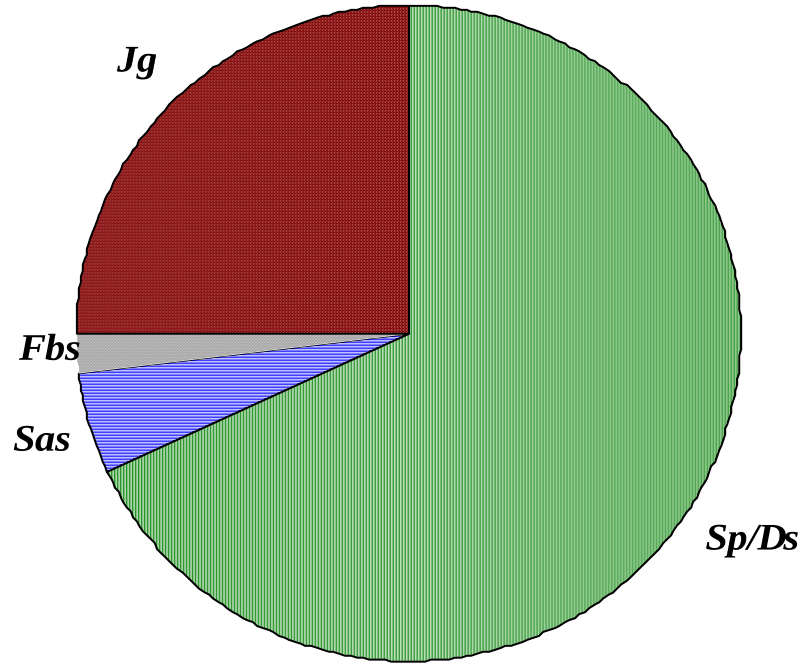
9 SET sites established 2003
Bay Front
High Marsh
Impoundment 1
IP1
HQ
BP
WC


Bay Front
Accretion = 2.74 mm yr-1
R2 = 0.98
mm Above 2003
Year
High Marsh
Accretion = 2.40 mm yr-1
R2 = 0.98
mm Above 2003
Year
Restored IP 1
Accretion = 1.85 mm yr-1
R2 = 0.92
mm Above 2003
Year
MHW Above 2000
RSLR = 7.92 mm yr-1
R2 = 0.65
mm Above 2000
Year


Accretion at Barn Island SET Sites
MHW Above 2000
7.92 mm yr-1
Bay Front
2.74 mm yr-1
High Marsh
2.40 mm yr-1
Restored IP
1.85 mm yr-1
Δ ≈ 4.3 mm yr-1
mm Above Start
120
100
80
60
40
20
0
1998
2000
2002
2004
2006
2008
2010
2012
2014
Year




Headquarters
Vegetation in 1988




Wequetequock Cove
Vegetation in 1988

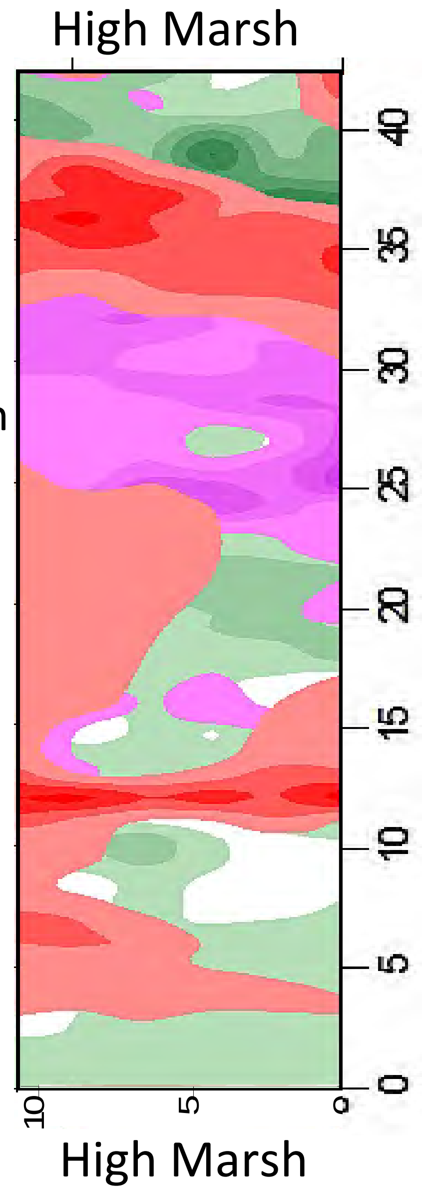
Miller and Egler 1951

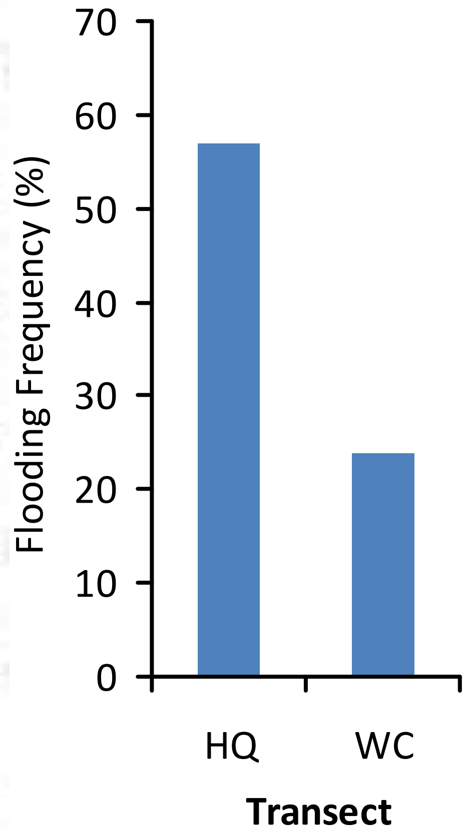
Warren and Niering 1993

# Δ Elevation ~ 9 cm

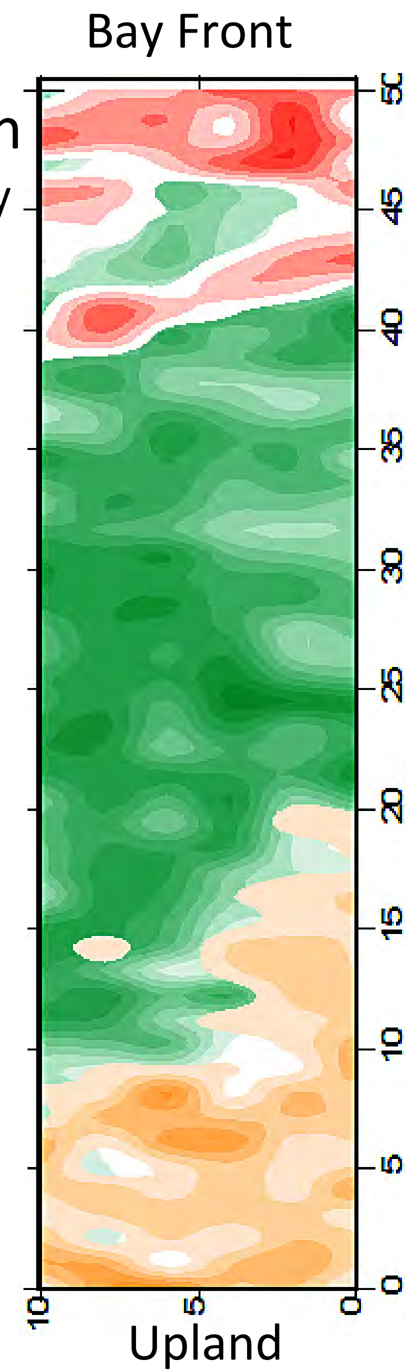
# Bellet's 1998 Barn Island Vegetation Transects

**HQ Section**
Mid-High Marsh




**WC Section**
Upland to Bay Front




- *Spartina alterniflora*
- *Spartina patens*
- *Juncus gerardii*
- Mixed Forbs

# Bellet's re-survey of Cotterll Marsh Vegetation Transects

- Spartina alterniflora
- Spartina patens
- Juncus gerardi
- Total forbs

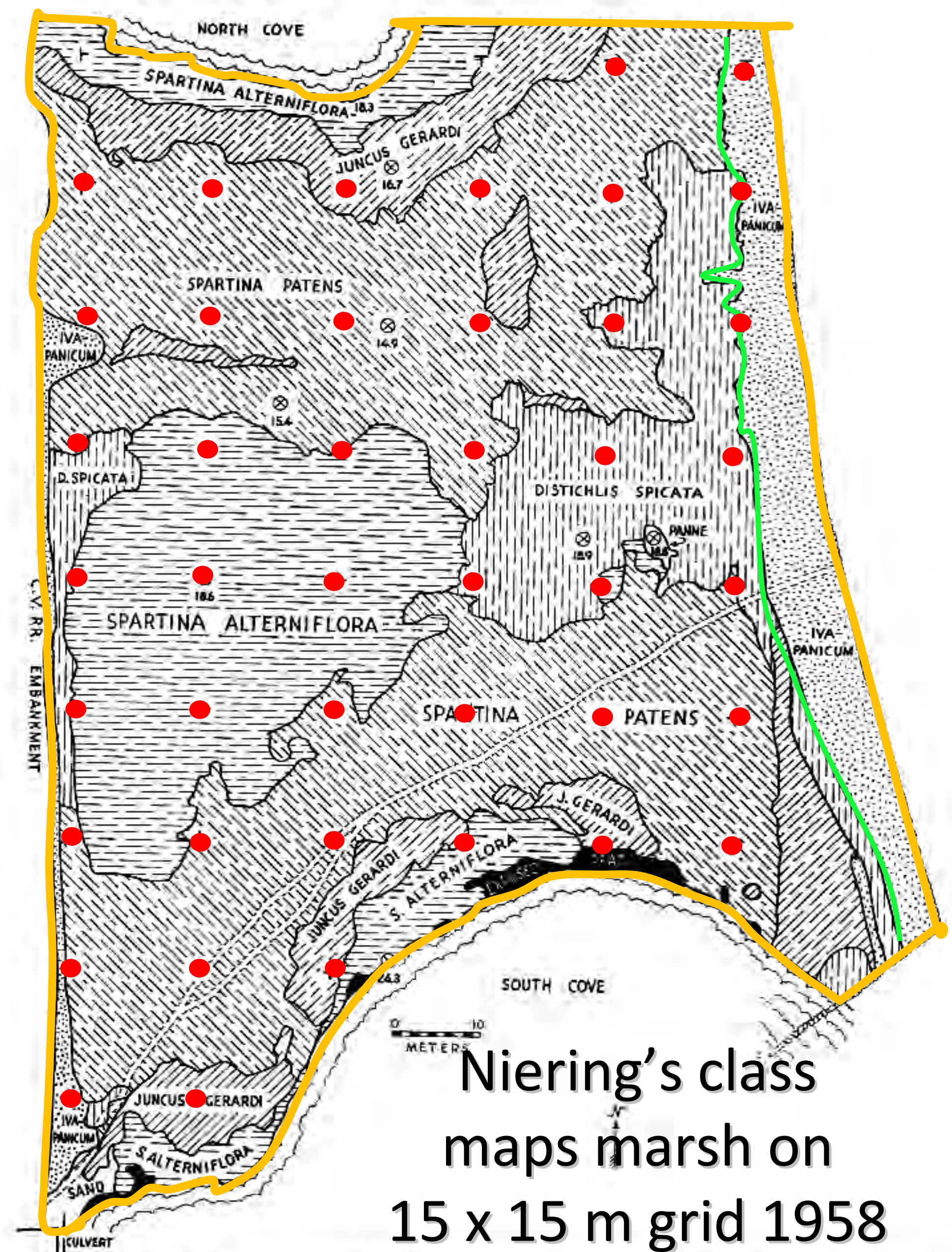
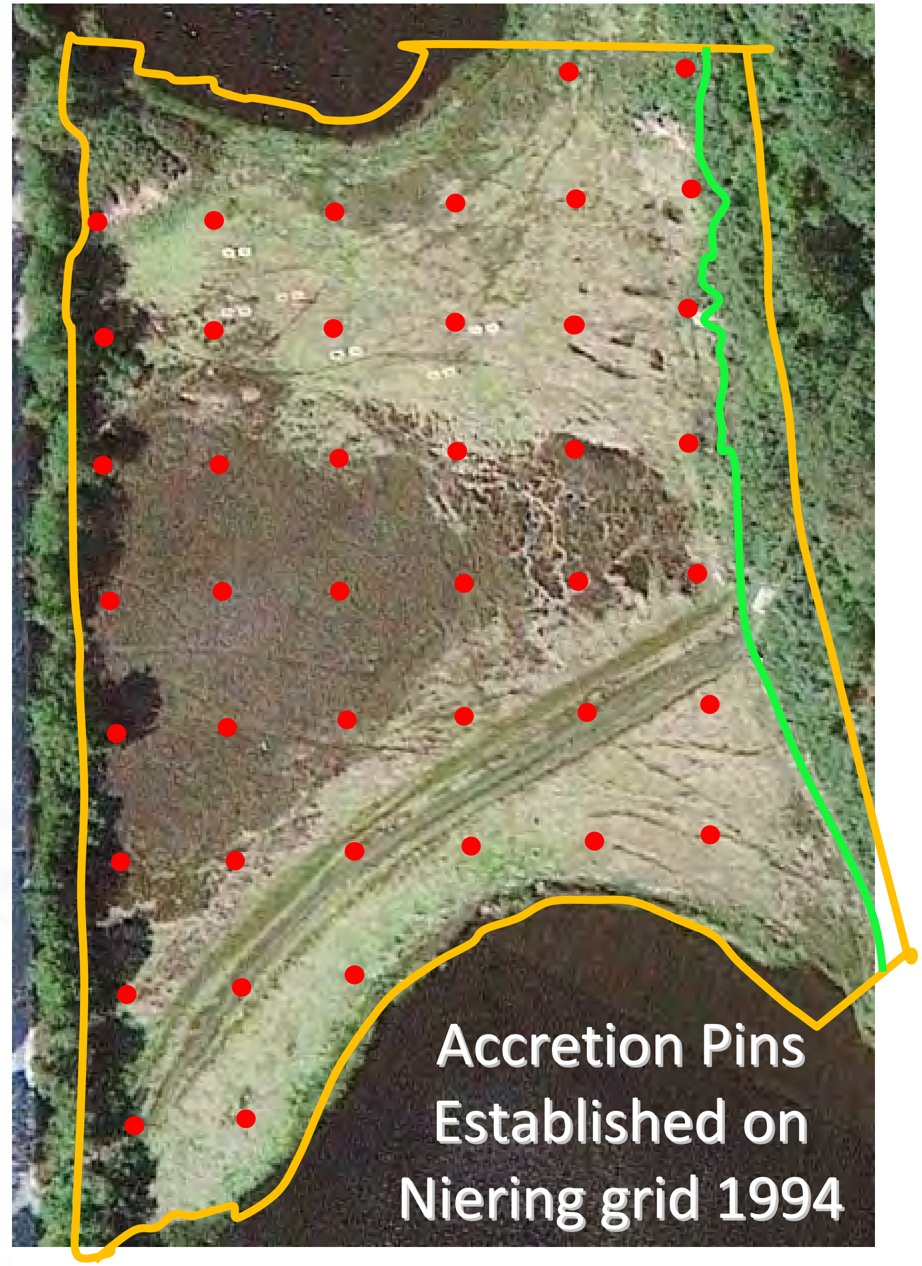
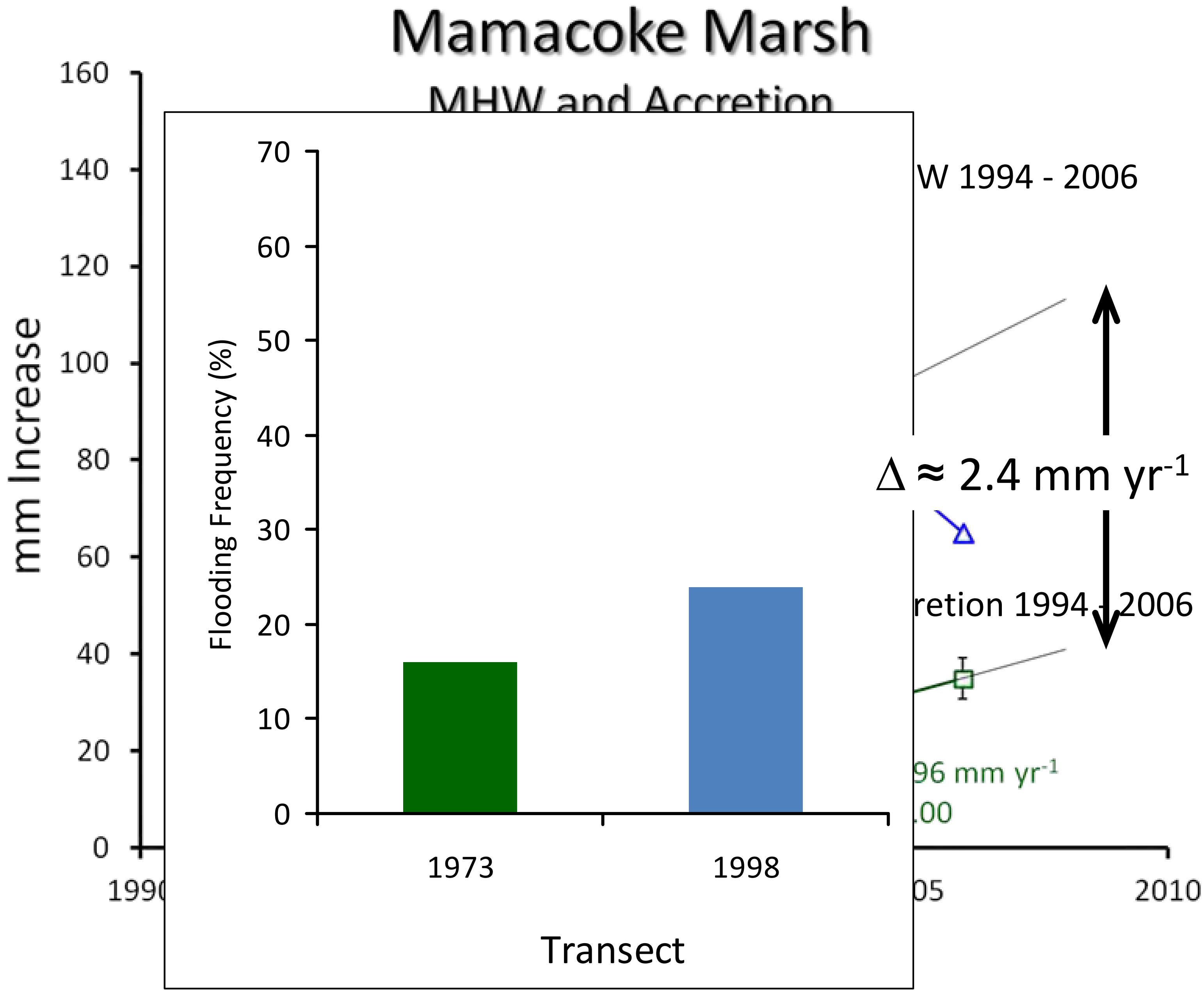
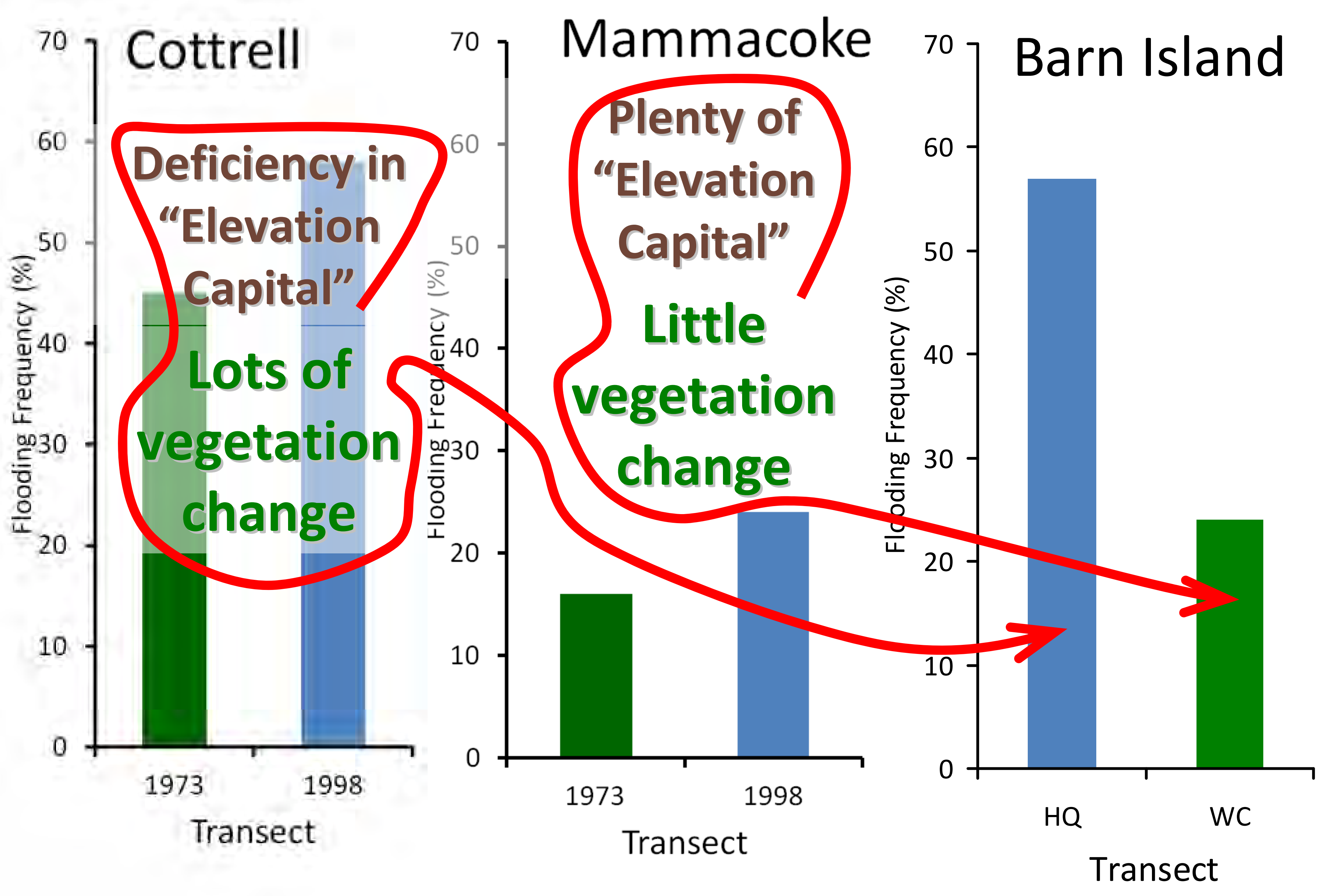



*Fig. 1. Map showing zonation of the vegetation on the Mamacoke marsh. The position of the corners of the permanent 15 x 15 m. quadrats are indicated. Points at which salinity measurements were taken are shown by circles, and low-tide salinity values are given in number of grams of salts per 1,000 grams of sea-water.*





Mamacoke Marsh
MHW and Accretion
mm Increase
160
140
120
100
80
60
40
20
0
1990
05
2010
W 1994 - 2006
retion 1994 - 2006
96 mm yr-1
.00
Δ ≈ 2.4 mm yr-1
Flooding Frequency (%)
70
60
50
40
30
20
10
0
1973
1998
Transect


Cottrell
Deficiency in "Elevation Capital"
Lots of vegetation change
Flooding Frequency (%)
70
60
50
40
30
20
10
0
1973
1998
Transect
Mammacoke
Plenty of "Elevation Capital"
Little vegetation change
Flooding Frequency (%)
70
60
50
40
30
20
10
0
1973
1998
Transect
Barn Island
Flooding Frequency (%)
70
60
50
40
30
20
10
0
HQ
WC
Transect

# Summary

- Accretion on the three eastern LIS marshes studied is NOT keeping up with RSLR.
- They are loosing relative elevation at *ca.* 2.5 – 4.5 mm $yr^{-1}$
- Marshes starting with high "elevation capital" - Wetequetock Cove & Mamacoke – have been relatively stable as flooding frequencies have increased to *ca.* 25 – 30%.
- *Sp/Ds* meadows continue to dominate the high marsh on these systems.
- Marshes with initially low "elevation capital" – Headquarters & Cottrell - now have hydroperiods close to low marsh values, >55%.
- *Sp/Ds* meadows are being converted to mixed forbs and stunted *Sa* on these systems.


Great thanks to
a pair of
talented &
very patient
collaborators!

# Nels Barrett

NRCS

# Ron Rozsa

CT DEP

(retired)

# Financial, logistical, & technical support for this work has come from:

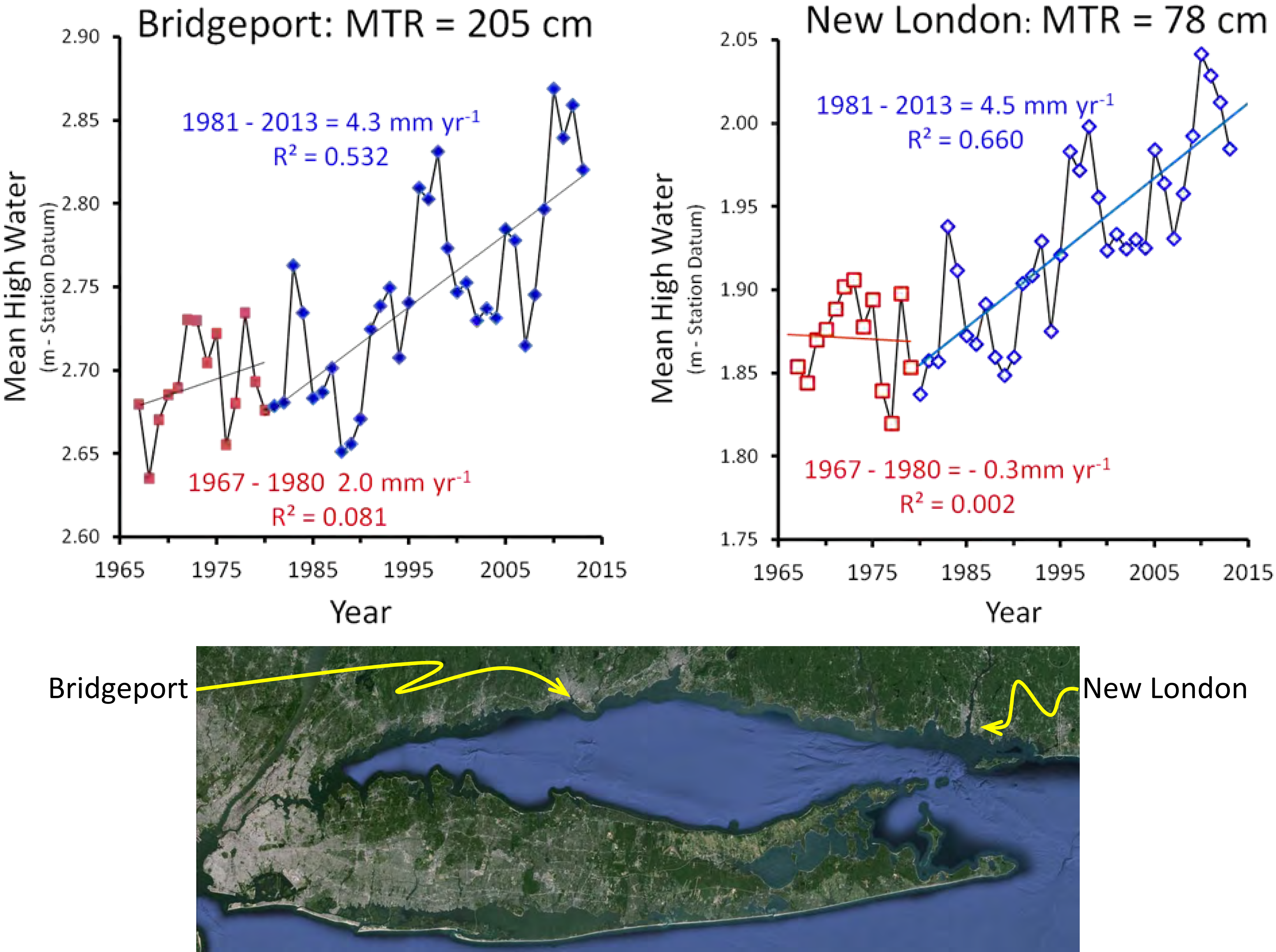
LONG ISLAND SOUND STUDY
A PARTNERSHIP TO RESTORE AND PROTECT THE SOUND

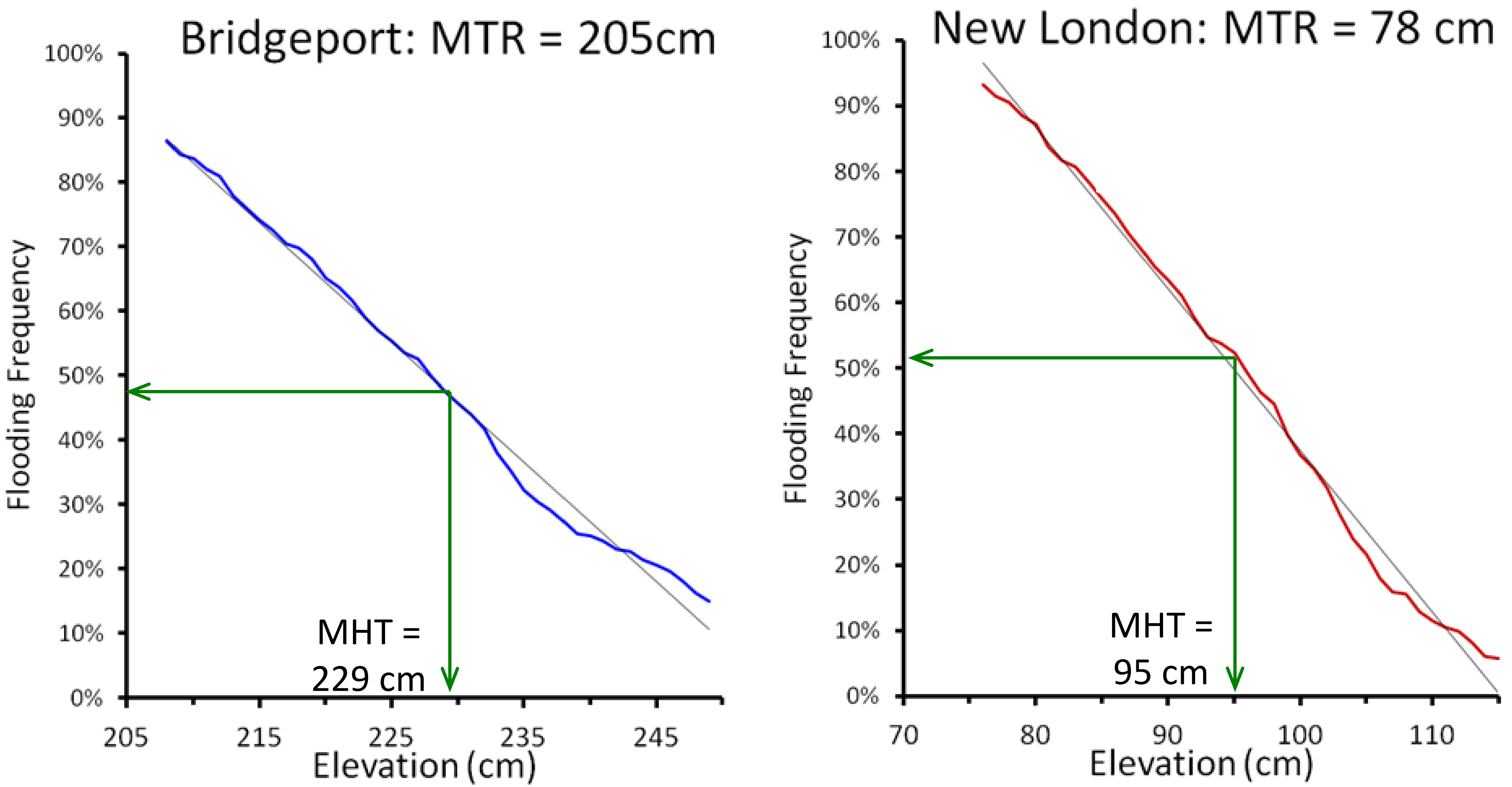
CONNECTICUT ENERGY ENVIRONMENT
Department of
ENERGY & ENVIRONMENTAL PROTECTION

USDA
Natural Resources Conservation Service

CONNECTICUT COLLEGE
Jean C. Tempel Professorship in Botany


Thank you
Questions?


Bridgeport: MTR = 205 cm
1981 - 2013 = 4.3 mm yr-1
R2 = 0.532
1967 - 1980 2.0 mm yr-1
R2 = 0.081
Mean High Water
(m - Station Datum)
2.90
2.85
2.80
2.75
2.70
2.65
2.60
1965
1975
1985
1995
2005
2015
Year
New London: MTR = 78 cm
1981 - 2013 = 4.5 mm yr-1
R2 = 0.660
1967 - 1980 = - 0.3mm yr-1
R2 = 0.002
Mean High Water
(m - Station Datum)
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1965
1975
1985
1995
2005
2015
Year
Bridgeport
New London




Summer 2013 Hydroperiods at New London & Bridgeport

Hydroperiod Increase for a given relative elevation loss is *ca.* 30% greater in eastern LIS than in the western Sound.

# Marsh elevation monitoring efforts and conservation strategy development by the Nature Conservancy on Long Island, NY

Adam Starke

Marine-Coastal Conservation Coordinator

# Our initial goal

The mission of The Nature Conservancy is to conserve the lands and waters on which all life depends.

Our vision is to leave a sustainable world for future generations.

## Protect LI Salt Marshes:

What impacts can we address?

How?

Natural Function

‘enabling conditions’

# Wetlands need a few key things

To keep pace with Sea Level Rise and stay viable into the future:

- **Space to migrate**
  - Sediment to grow

# Migrating Landward...

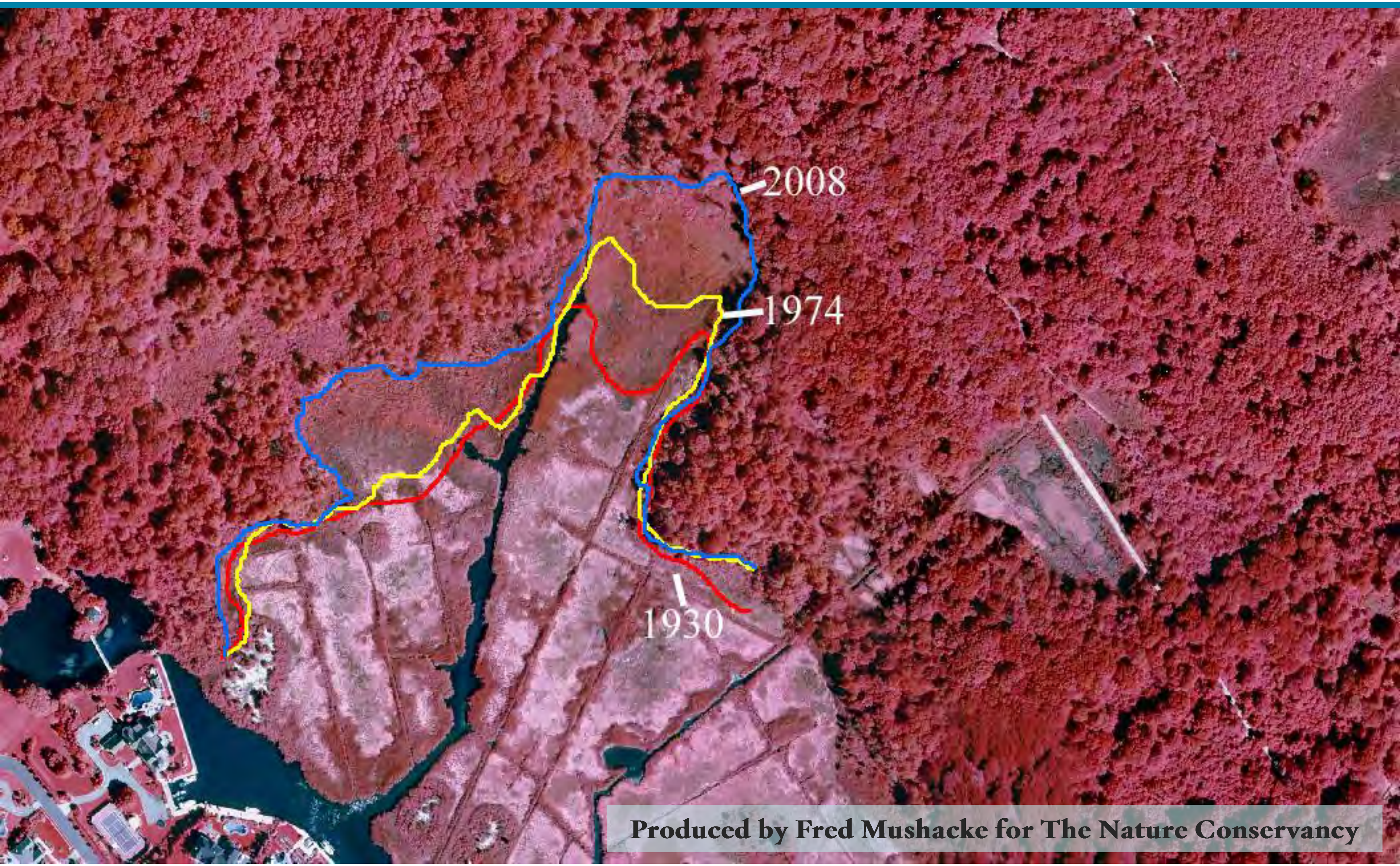
Example from Pine Neck Sanctuary in Quogue

# Migrating Landward...

Example from Cedar Beach- Southold NY

The Nature Conservancy
Protecting nature. Preserving life.

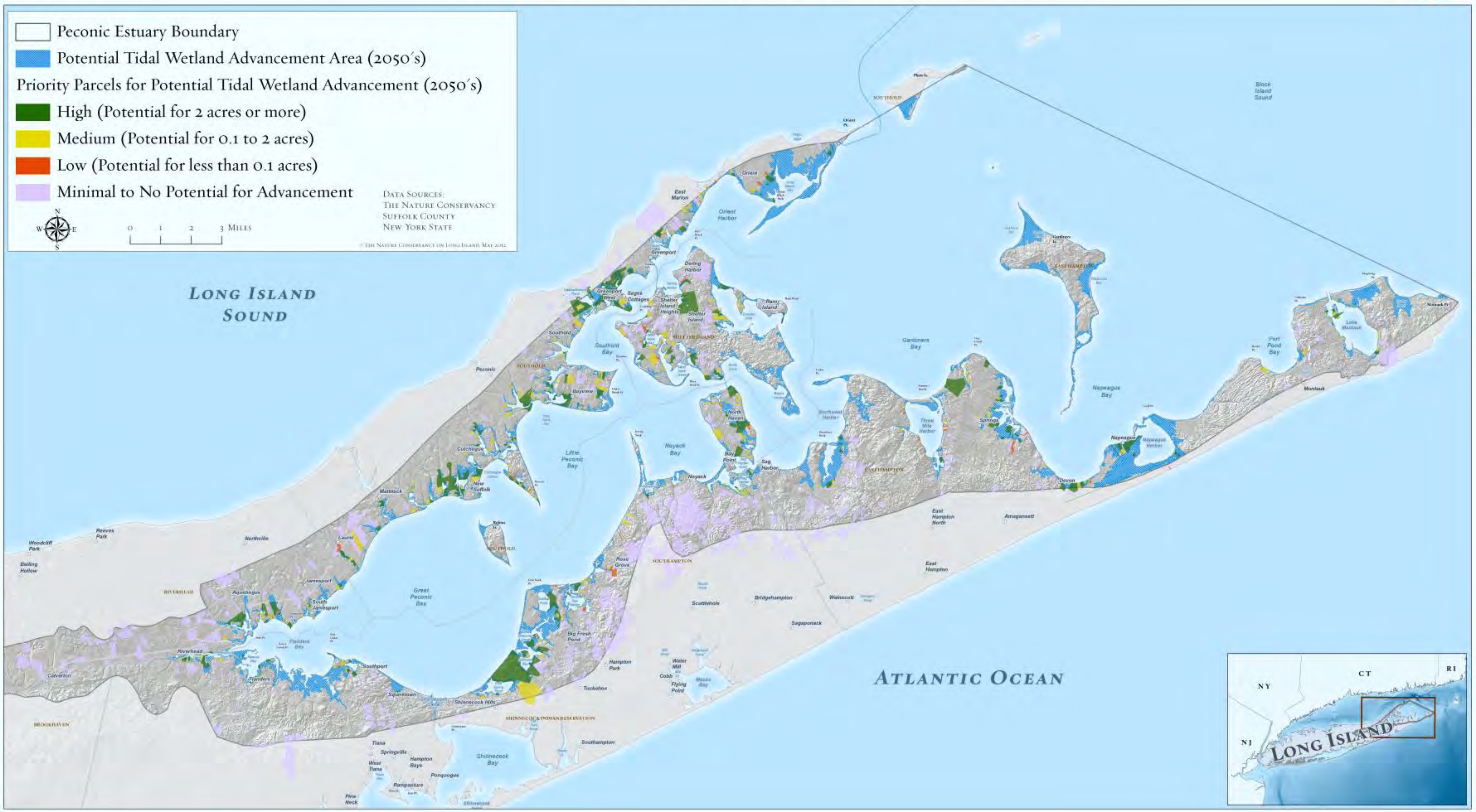
# Marsh Migration: Gardiner County Park



# Our initial goal-
# Land Protection....

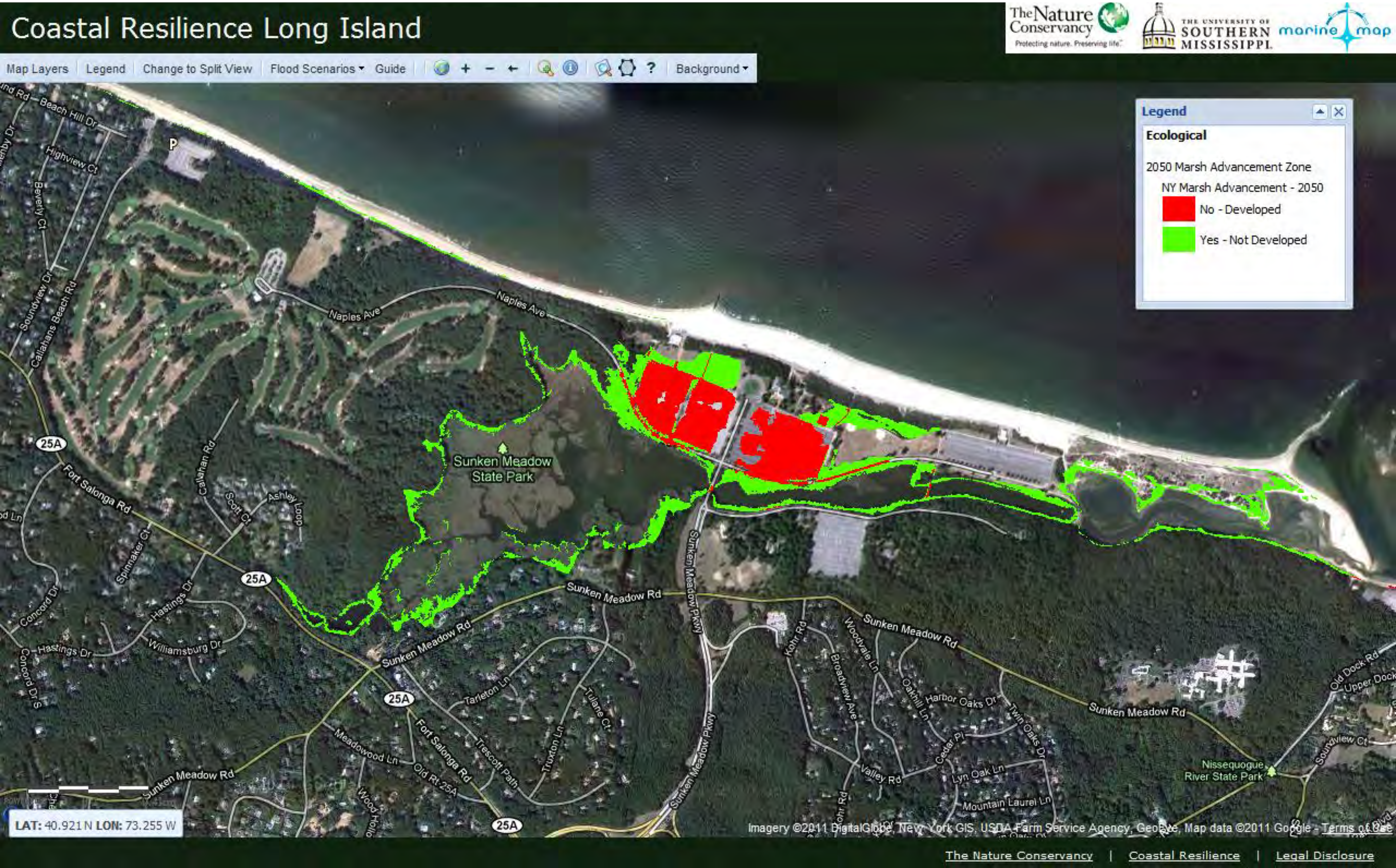
# Critical Lands Protection Strategy
# ---Parcel Prioritization---

## CLPS Parcels With Potential For Tidal Wetland Advancement
## 2050's (Decadal Average) Sea Level Rise Projection



# Potential Marsh Advancement Zone in the 2050's:

red areas are at a suitable elevations for marsh migration but are developed; green areas are at a suitable elevation and are not currently developed



# Wetlands need a few key things

The Nature Conservancy
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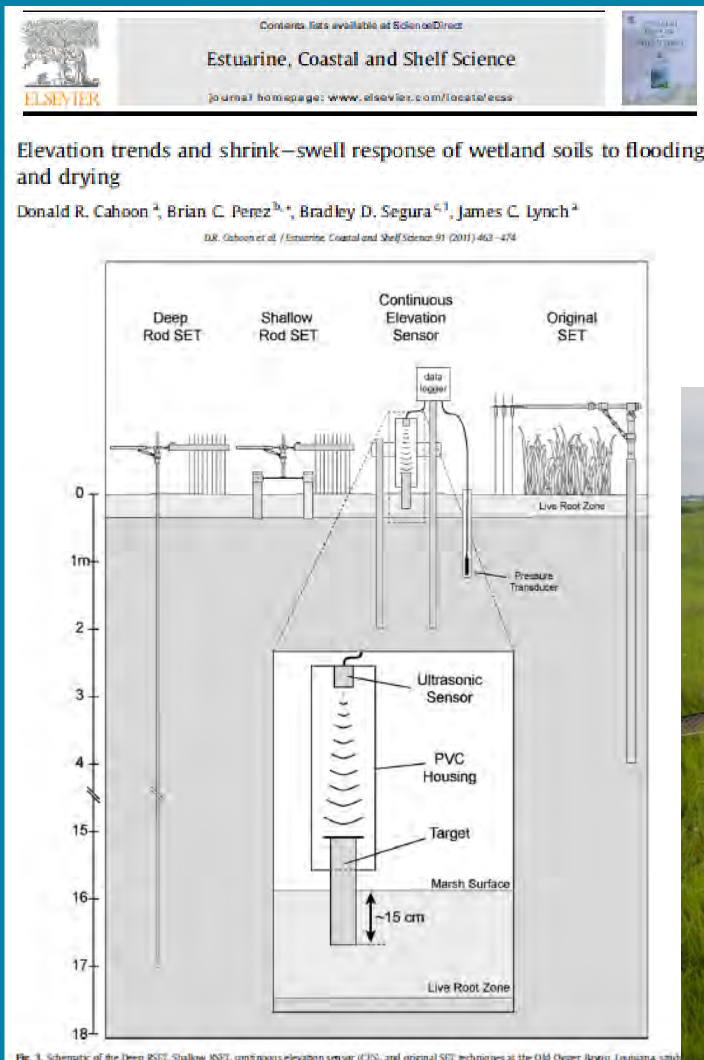
# SET-MH Monitoring


Contents lists available at ScienceDirect
Estuarine, Coastal and Shelf Science
journal homepage: www.elsevier.com/locate/ecss

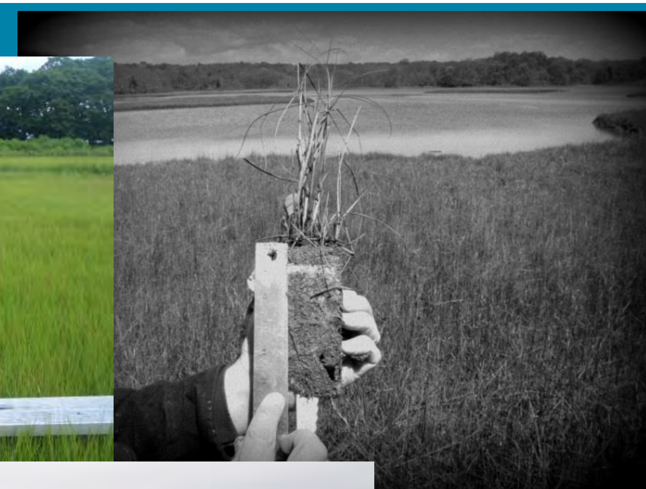
Elevation trends and shrink–swell response of wetland soils to flooding and drying

Donald R. Cahoon[a], Brian C. Perez[b,*], Bradley D. Segura[c,1], James C. Lynch[a]

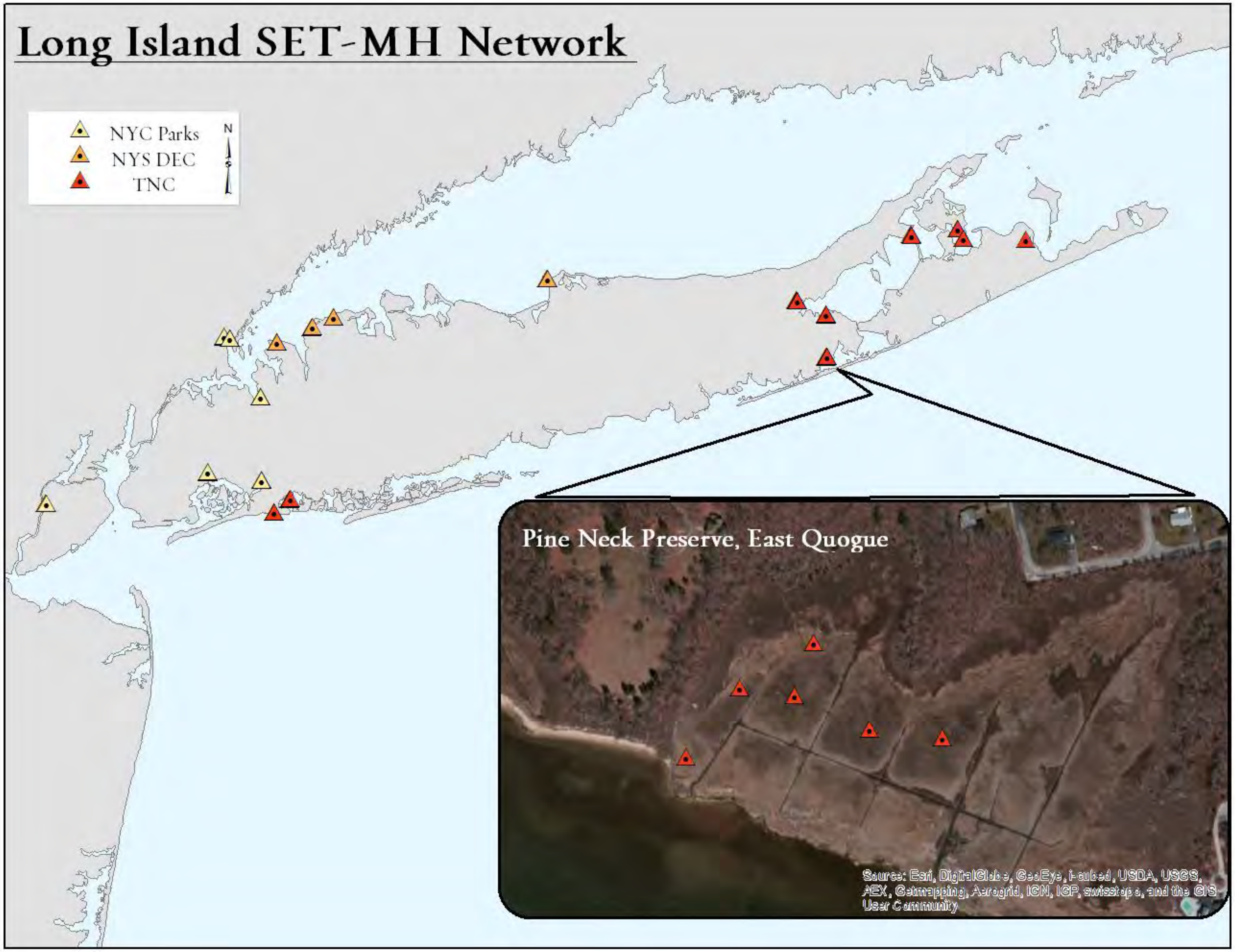
D.R. Cahoon et al. / Estuarine, Coastal and Shelf Science 91 (2011) 463–474



Fig. 3. Schematic of the Deep RSET, Shallow RSET, continuous elevation sensor (CES), and original SET techniques at the Old Oyster Bayou, Louisiana, study



# SET-MH Across Long Island



# Water Quality!

LETTER

doi:10.1038/nature11533

## Coastal eutrophication as a driver of salt marsh loss

Linda A. Deegan[1], David Samuel Johnson[1,2], R. Scott Warren[3], Bruce J. Peterson[1], John W. Fleeger[4], Sergio Fagherazzi[5] & Wilfred M. Wollheim[6]

388 | NATURE | VOL 490 | 18 OCTOBER 2012

ECOLOGY

## The big picture of marsh loss

A landscape-scale experiment shows that excessive nutrient levels can cause the loss of salt marshes — a result that was not seen in smaller studies. This illustrates the value of large-scale, long-term studies in ecology. SEE LETTER P.388

STEVEN C. PENNINGS

| NATURE | VOL 490 | 18 OCTOBER 2012

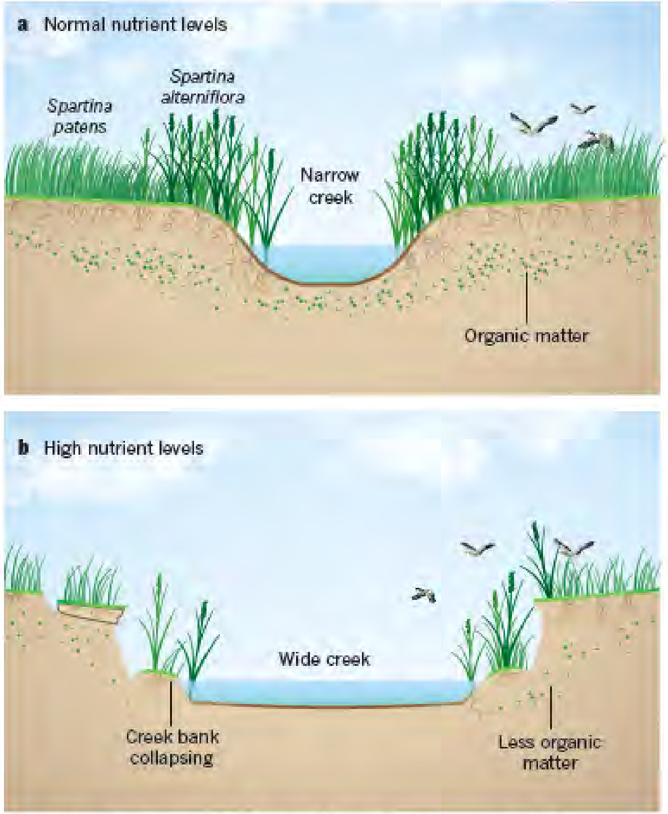



**Figure 1 | Nutrients and salt-marsh loss.** Over the course of nine years, Deegan *et al.*[5] added nutrients to the water at the mouth of tidal creeks at Plum Island Estuary, Massachusetts, when the tide was rising, so that the nutrients entered the marshes around the creeks. The marshes in this region are dominated by two grasses: *Spartina patens* on the marsh platform and *Spartina alterniflora* along creek banks. **a**, When nutrient supplies to estuaries are normal, marshes are dissected by narrow tidal creeks, the grasses produce substantial root growth and the soil contains lots of organic matter. **b**, By contrast, when nutrients were added, the authors observed that plants produced fewer roots, organic matter decomposed more rapidly and creek banks collapsed, leading to wider creeks and less vegetated marsh, with narrower bands of *S. alterniflora*.

The Nature Conservancy

Protecting nature. Preserving life.™

# Wetlands need 3 key things

To keep pace with Sea Level Rise and stay viable into the future:

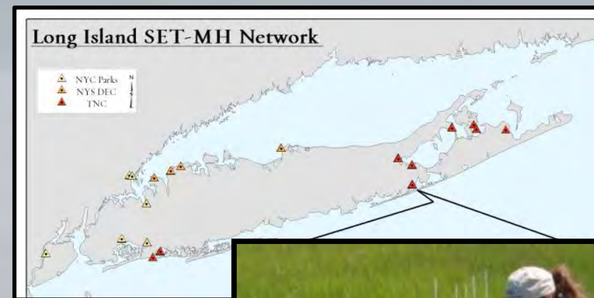
- Space to move
- Sediment
- **Clean water!**

The Nature Conservancy
Protecting nature. Preserving life.™

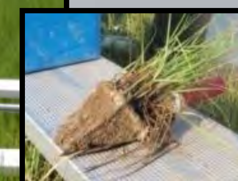
# Shallow SET installations

# Network of Marsh Elevation Stations to measure Salt Marsh Response to SLR:

- Long Island SET Network



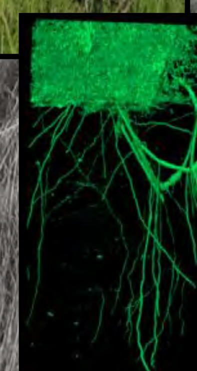

- Elevation & Surface Accretion


- Hydrology


- Pore water geochemistry

- Belowground production and respiration





# Hurricane Sandy Coastal Resiliency Competitive Grant Program

North East Marsh Elevation Monitoring Cooperative

# Adaptation


SUFFOLK COUNTY GOVERNMENT
Long Island, New York
County Executive, Steven Bellone
Select Language
Home | Government | Online Services | How Do I? | Business | Visitors | Community | Public Safety

Listen

## Bellone Announces Major Initiative to Address Suffolk County's Declining Water Quality

Department: County Executive | Posted: 3/27/2014 | Views: 293

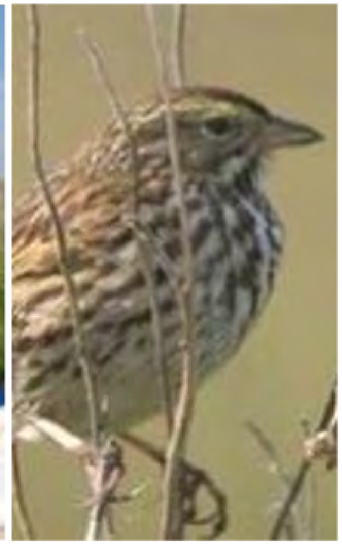
*'Reclaim Our Water' Initiative to Target Nitrogen Pollution Crisis*

*Proposal a comprehensive, multi-phased, infrastructure plan to reverse decades of nitrogen pollution in Long Island waterways*

**(Oakdale, NY-March 26, 2014)**—Suffolk County Executive Steve Bellone announced today the first step in a comprehensive, multi-phased infrastructure plan to begin to address Suffolk County's nitrogen pollution crisis. The 'Reclaim our Water' initiative would be the greatest investment in clean water infrastructure in generations.

# Can tidal marsh birds persist in the face of climate change?





Trina Bayard, Alyssa Borowske, Patrick Comins, Chris Field, Carina Gjerdrum, Chris Hill, Jason Hill, Selena Humphreys, Erin King, Sue Meiman, Margaret Rubega, Emma Shelly, Kira Sullivan-Wiley

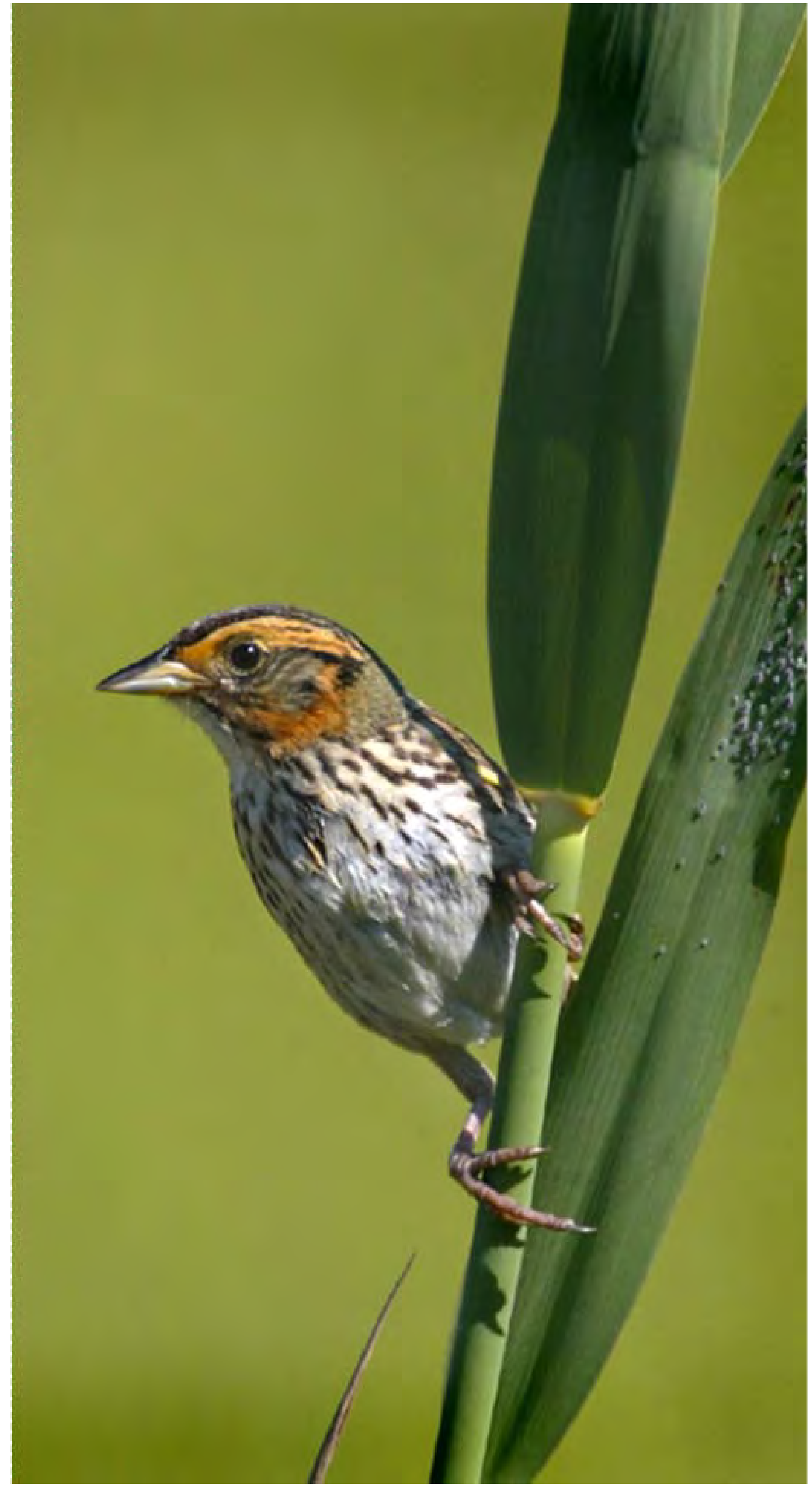
CONNECTICUT LIS·FUND PRESERVE THE SOUND J.H. Torrance Downes

CONNECTICUT DEPARTMENT ENVIRONMENTAL PROTECTION

CESE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Sea Grant Connecticut

# Why saltmarsh sparrow?

- IUCN “vulnerable”
- limited range
- unusual breeding system

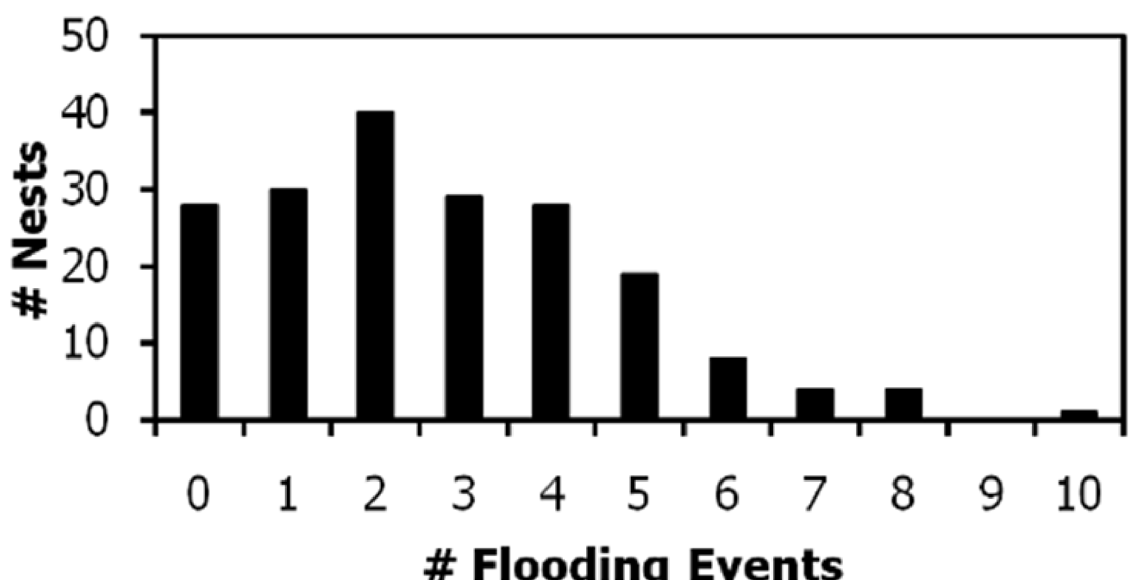
The “canary” in
the salt marsh.

*Specialized* - endemic to tidal marsh
*Representative* - nests prone to tidal flooding

# Most nest loss is due to tidal flooding


**2002-03 (136 nests)**
40% lost chicks to flooding

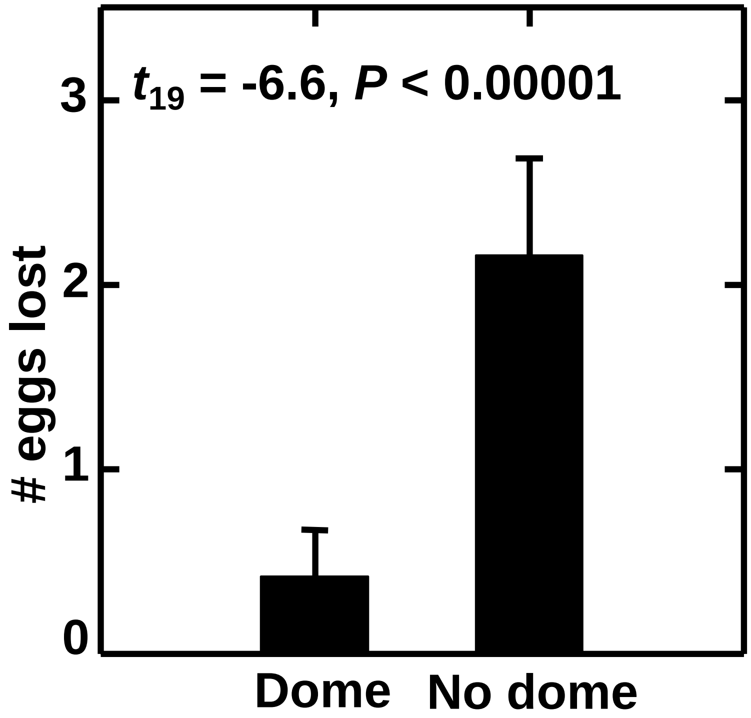
**2007-09 (191 nests)**
85% flooded at least once
54% failed due to flooding



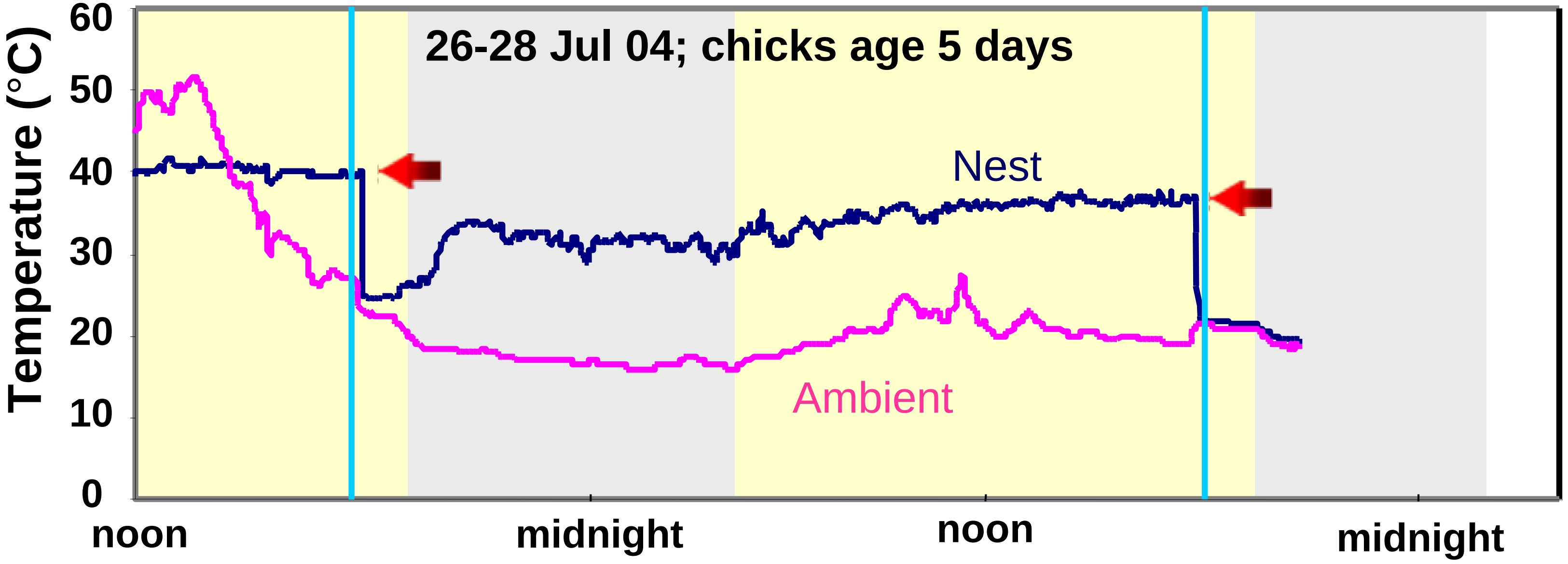

Gjerdrum et al. 2005 Condor; Bayard and Elphick 2011 Auk

# Behaviors to survive flooding

## Nest domes




## Mobile nestlings

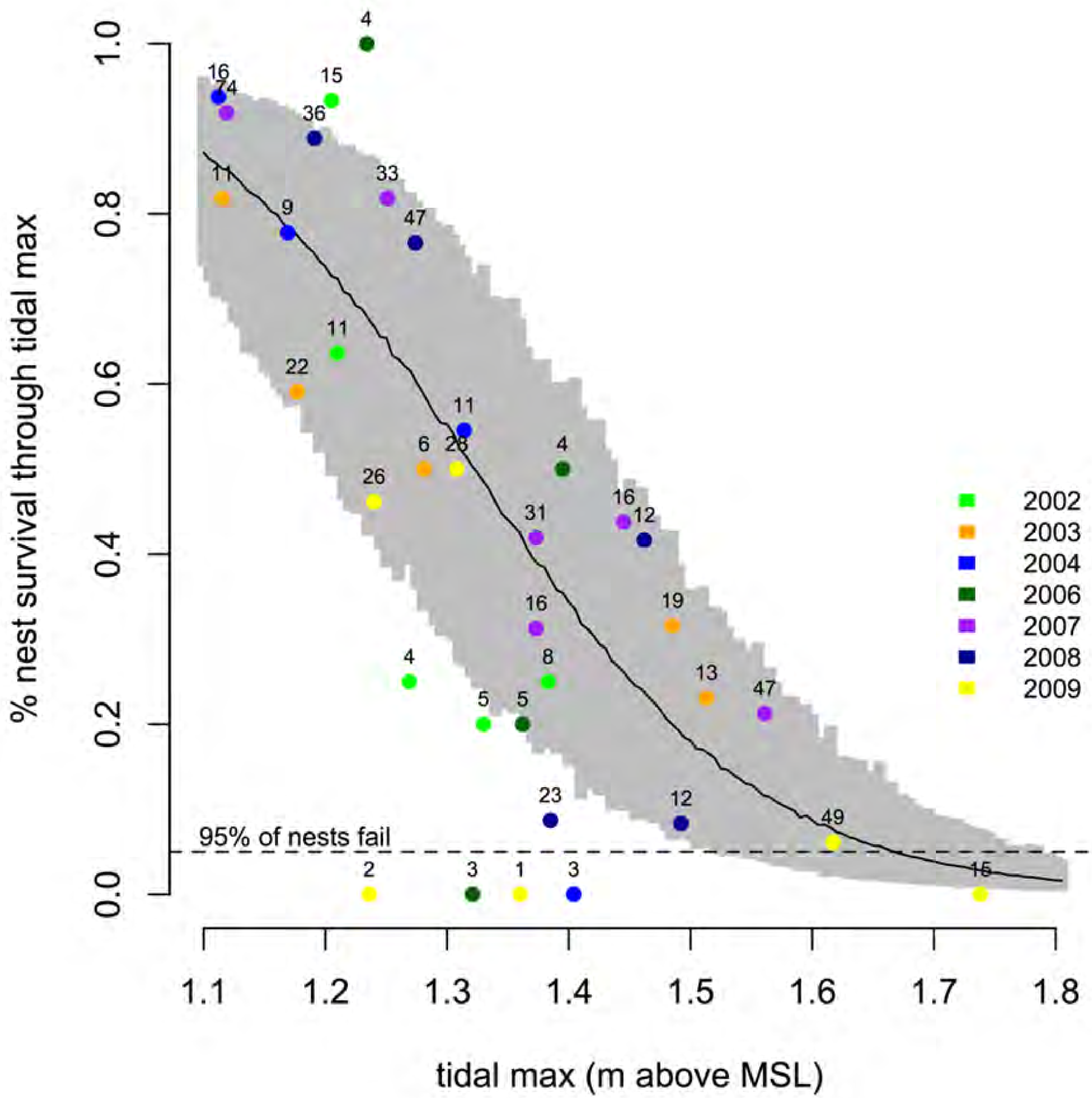



Humphries et al. 2007 JFO; Gjerdrum et al. 2008 Condor

# Nesting must fit between tidal cycles

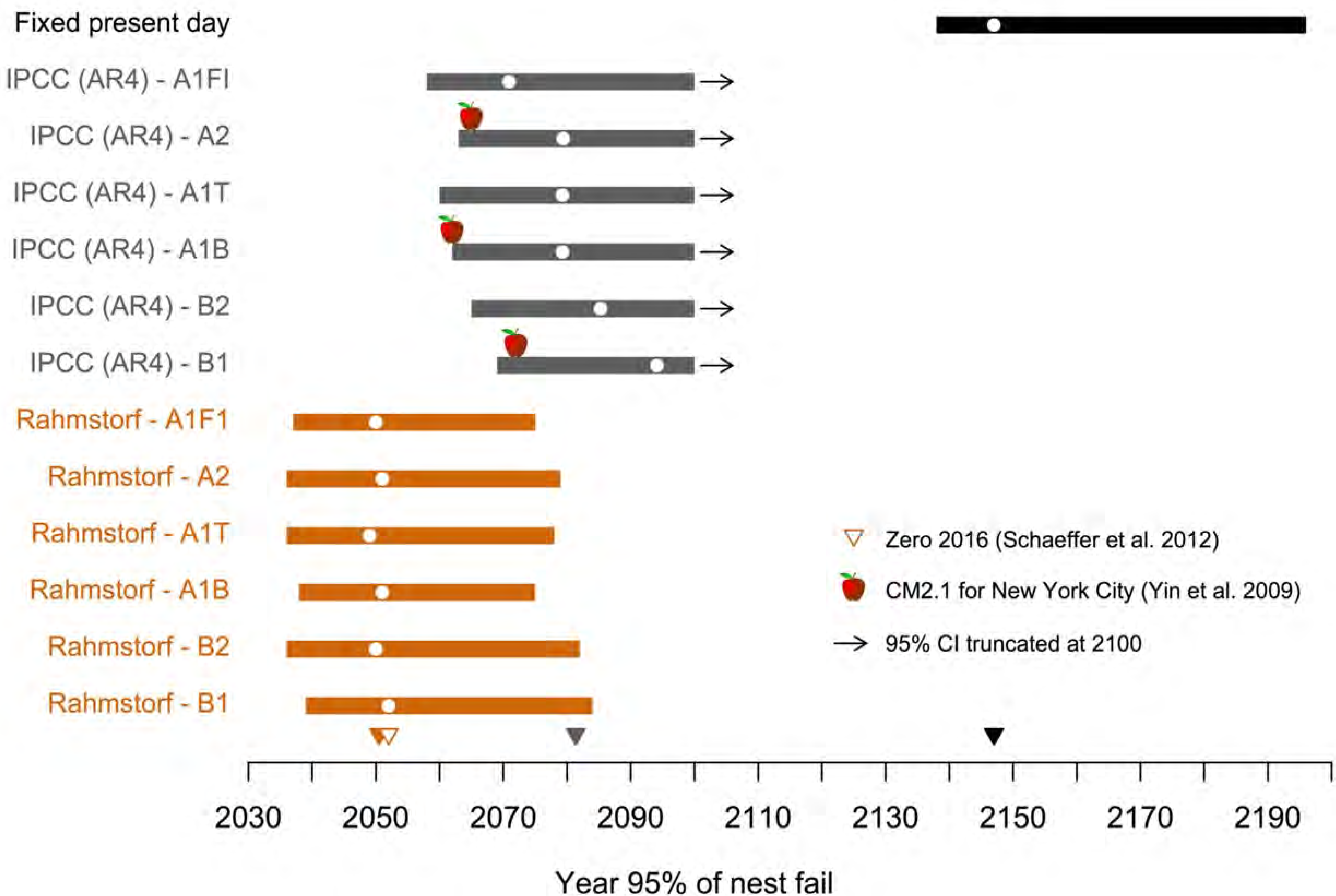
Egg-laying: ~4 d
Incubation: ~12 d
Nestling: ~10 d

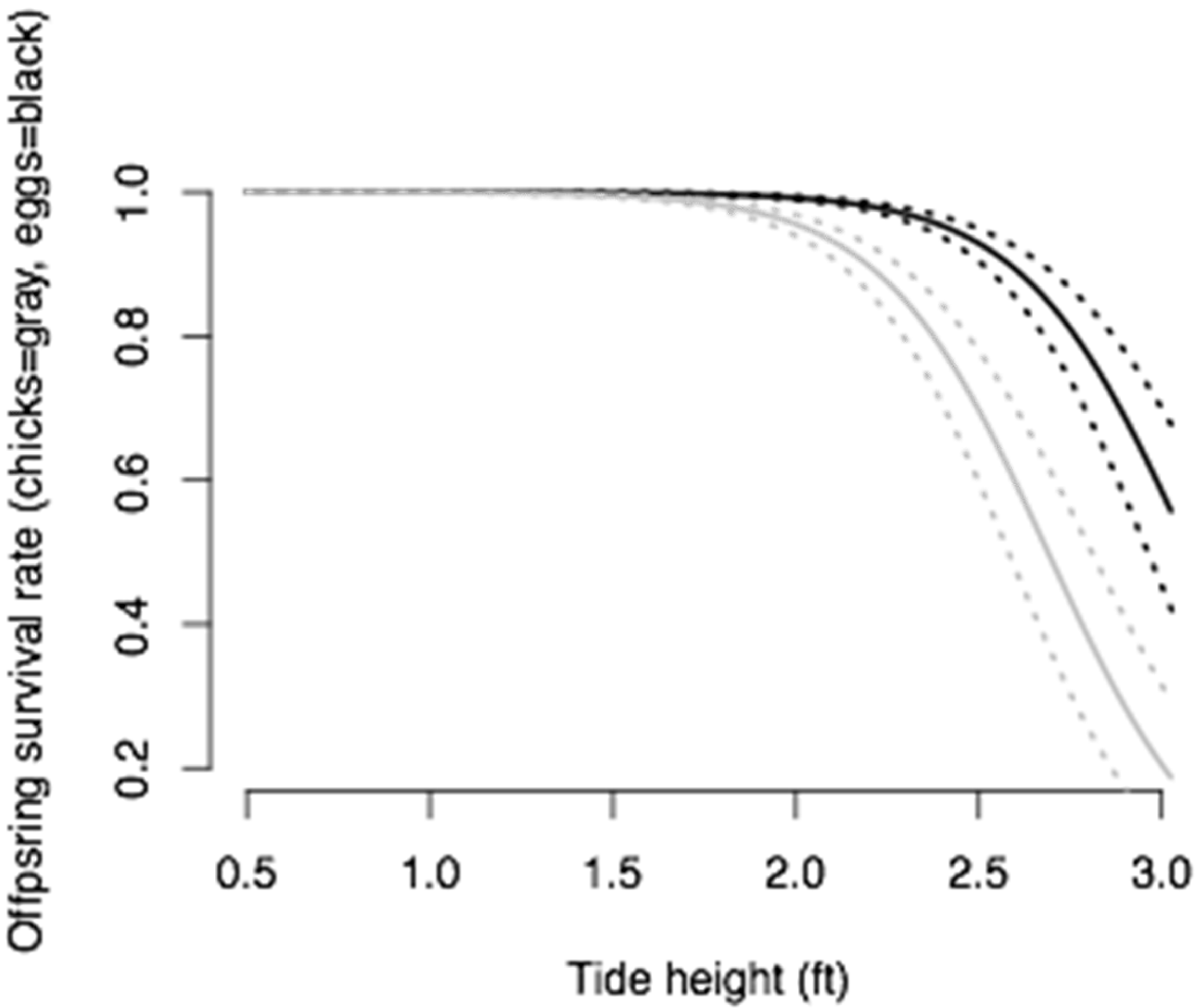
Total: ~26 d

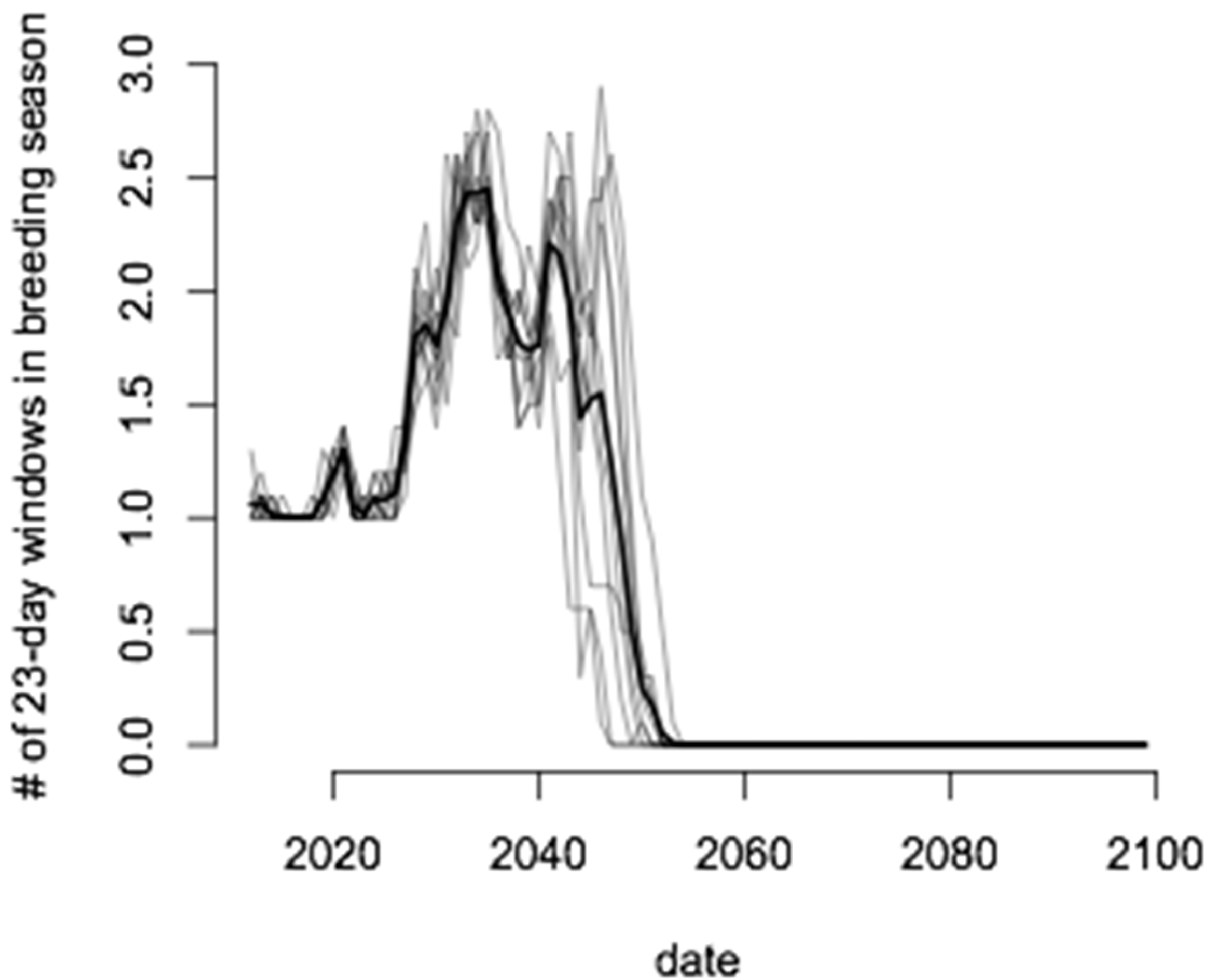


% nest survival through tidal max
tidal max (m above MSL)
1.0
0.8
0.6
0.4
0.2
0.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
95% of nests fail
2002
2003
2004
2006
2007
2008
2009

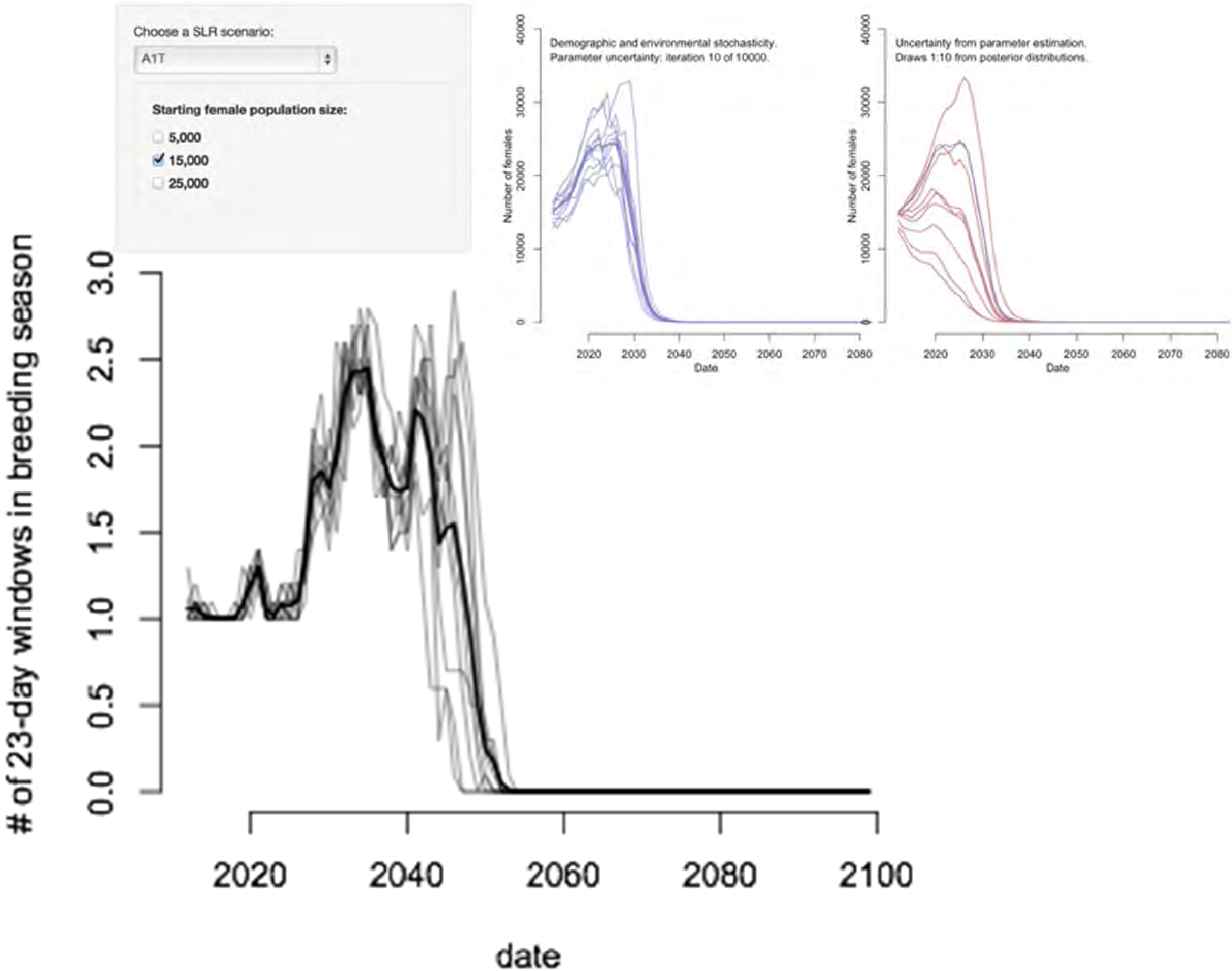
# When will reproduction fail?

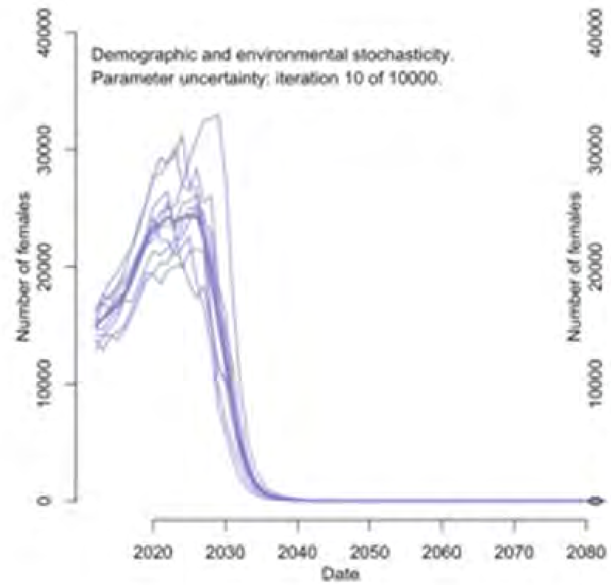


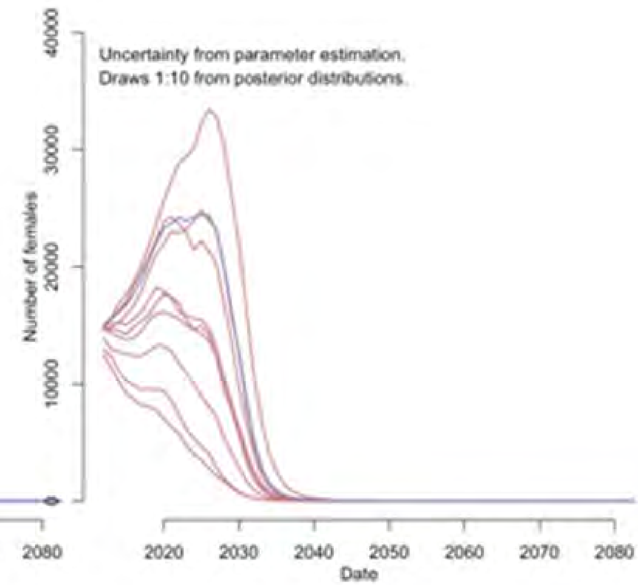

Offpsring survival rate (chicks=gray, eggs=black)
1.0
0.8
0.6
0.4
0.2
0.5
1.0
1.5
2.0
2.5
3.0
Tide height (ft)

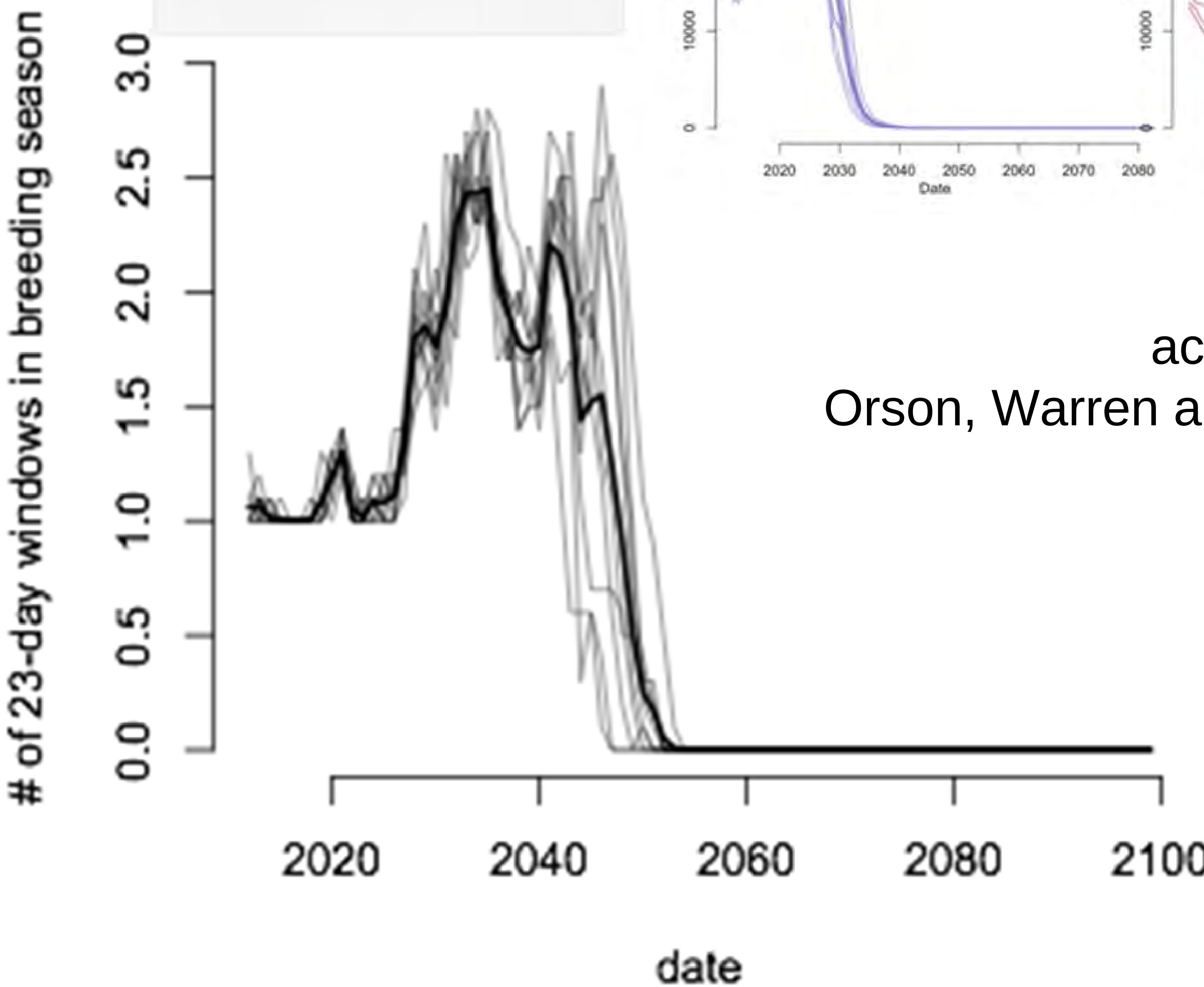


# of 23-day windows in breeding season
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2020
2040
2060
2080
2100
date


Choose a SLR scenario:
A1T
Starting female population size:
5,000
15,000
25,000
Demographic and environmental stochasticity.
Parameter uncertainty: iteration 10 of 10000.
Number of females
Date
Uncertainty from parameter estimation.
Draws 1:10 from posterior distributions.
Number of females
Date
# of 23-day windows in breeding season
date


accretion based on
Orson, Warren and Niering (1998)

no transgression

# What about marsh restoration?

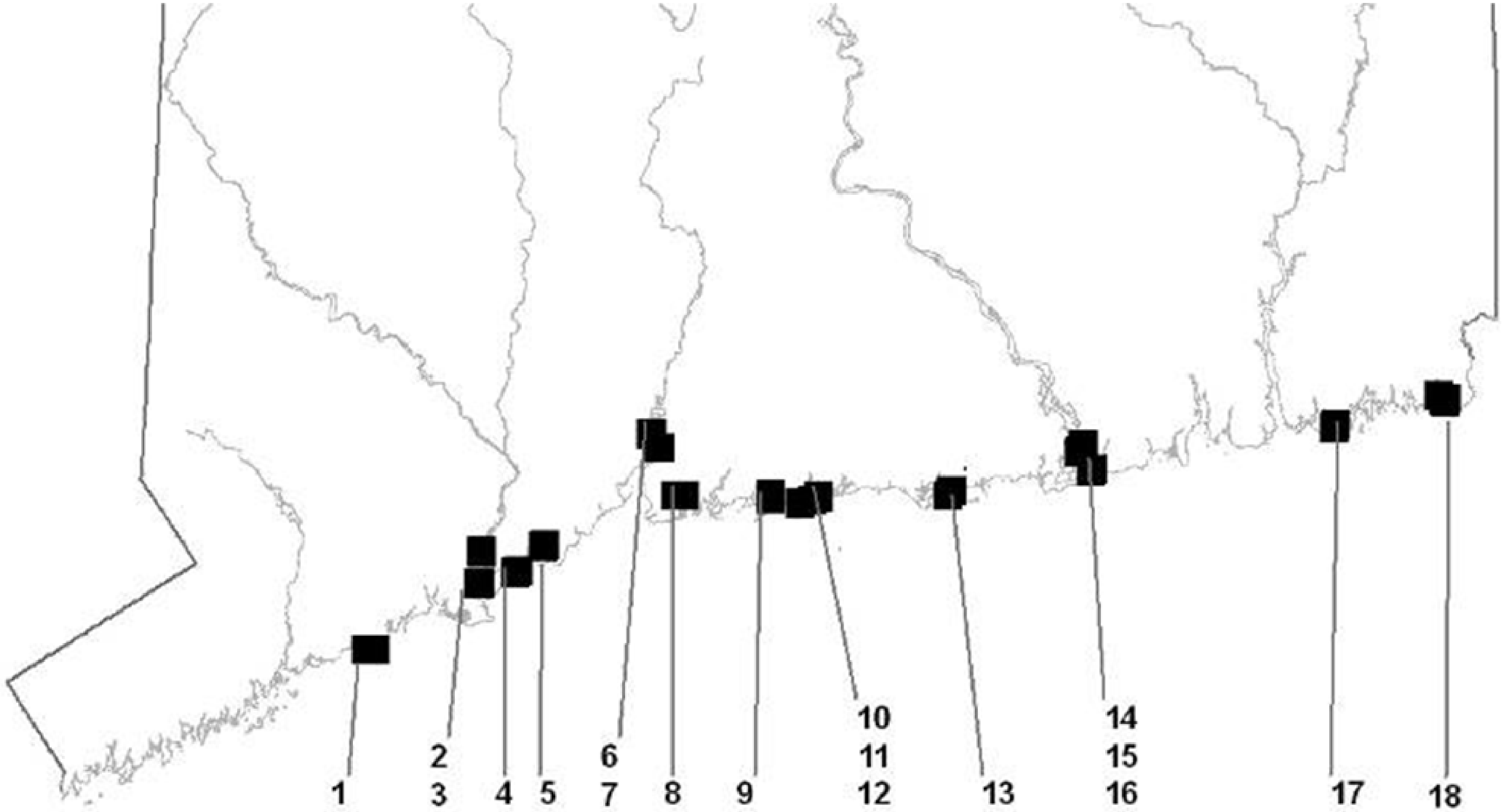
Tidal flow restoration

Barn Island WMA, CT

Direct Phragmites control


Lord’s Cove, CT

# CT restoration sites



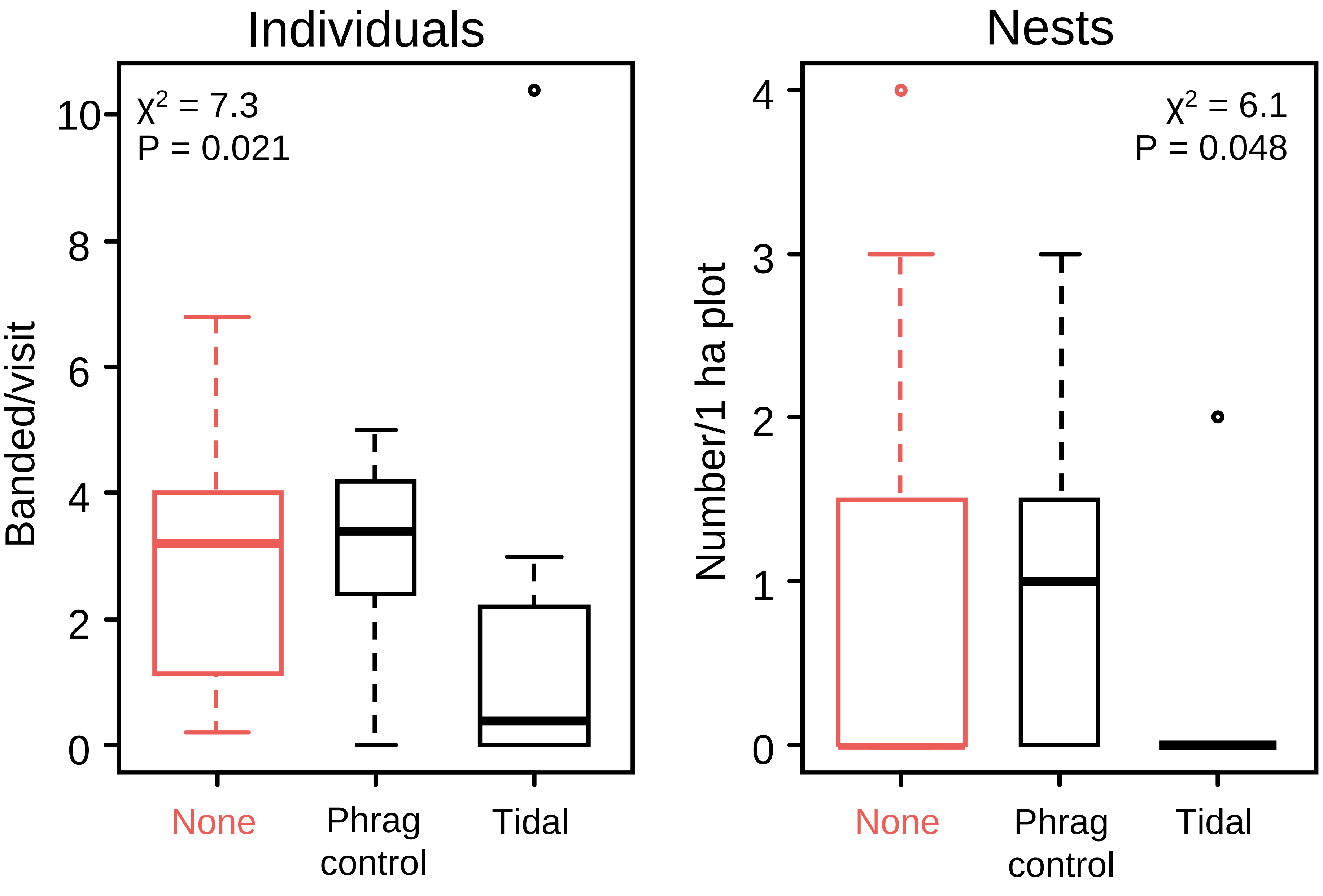

## How does restoration affect sparrows?

Reference sites = 19

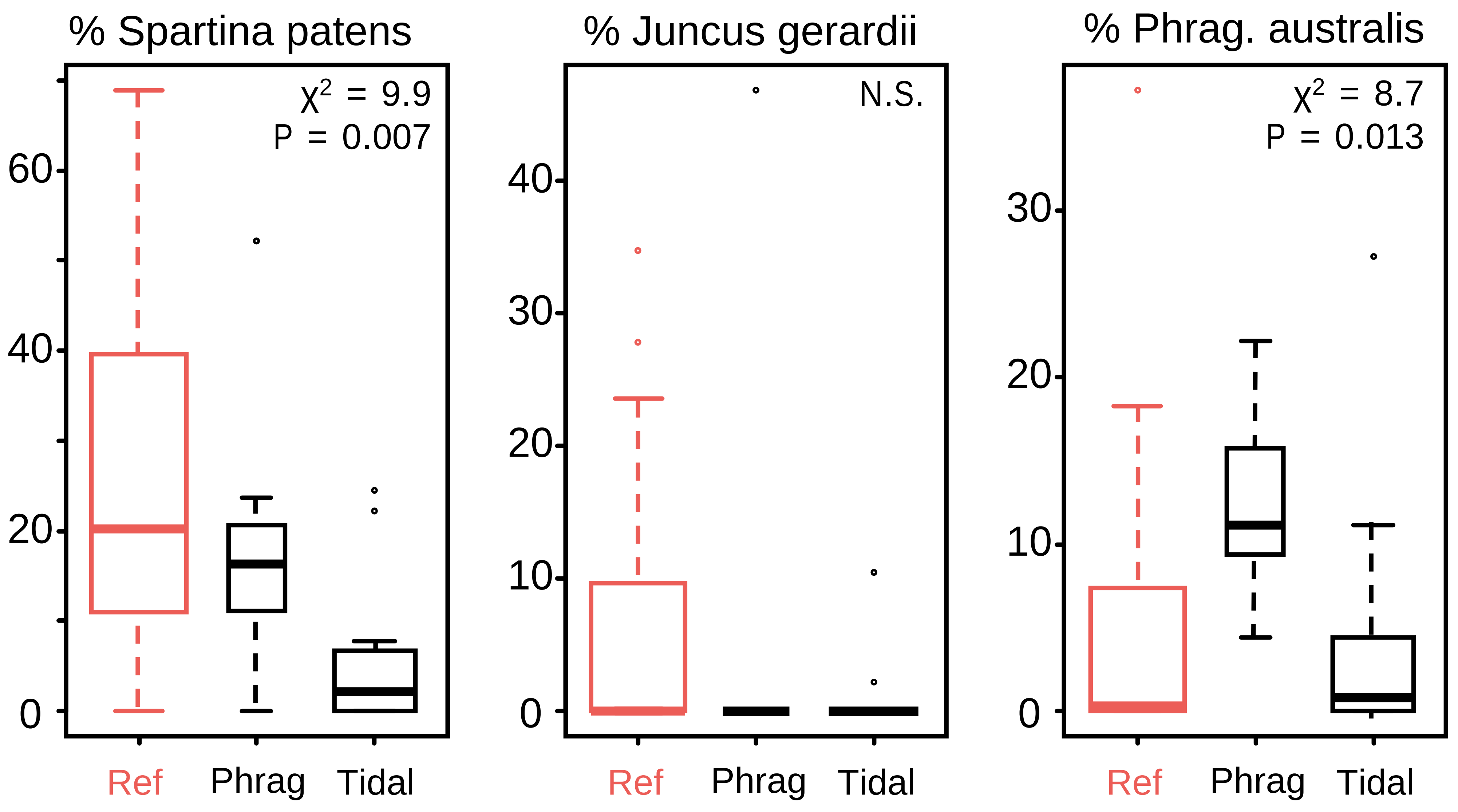
*Phragmites* control = 7

Tidal flow restoration = 14

Saltmarsh sparrows are rare in tidal flow restoration sites

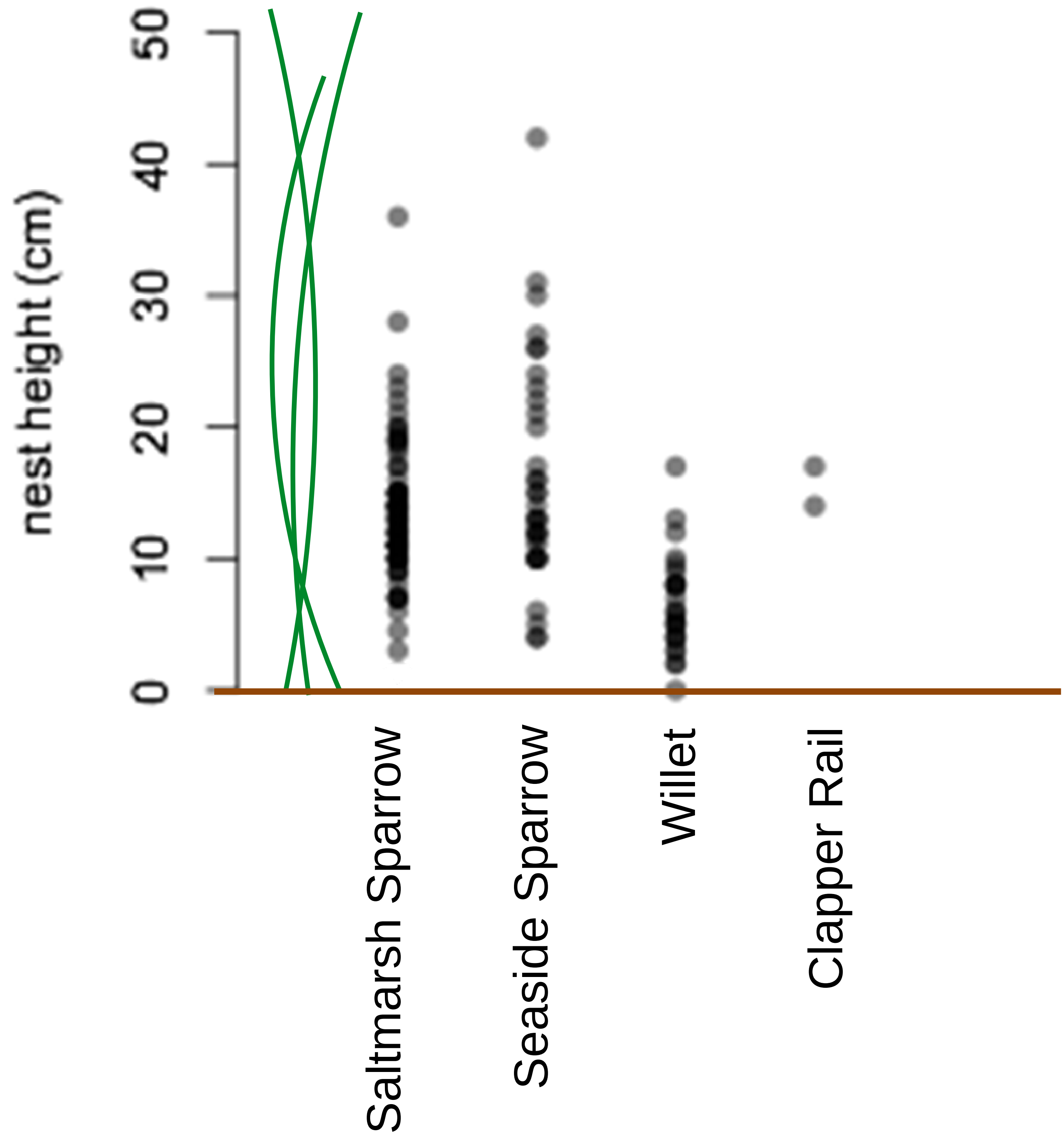


## … and high marsh plants are less common



# Other bird species appear unaffected …




nest height (cm)
0
10
20
30
40
50
Saltmarsh Sparrow
Seaside Sparrow
Willet
Clapper Rail

Shorebird transects statewide, covering 51 hectares

Shorebird transects statewide, covering 51 hectares

All species combined: 0.375 individuals/hectare

Shorebird transects statewide, covering 51 hectares

All species combined: 0.375 individuals/hectare

Greater and Lesser Yellowlegs
Least Sandpiper
Ruddy Turnstone
Black-bellied Plover
Short-billed Dowitcher

christopher.field@uconn.edu

chris.elphick@uconn.edu

# Salt Marsh Adaptation Strategies in Light of Sea Level Rise

**April 16, 2014**

**Wenley Ferguson**

SAVE THE BAY®
NARRAGANSETT BAY

# Introduction

- Impacts observed and quantified through RISMA and NBNERR Sentinel Sites
  - Ponded water
  - Barren peat
  - Reduced high marsh habitat
  - Increased mosquito breeding habitat
  - Eroding creek and outer marsh edge




Shallow ponded water


Barren peat


Mosquito breeding habitat


Narrow high marsh along upland edge; stunted vegetation

# Marsh erosion




# Adaptive Management

- During RISMA, sites were identified for adaptive management
- Techniques include:
  - Hand digging runnels
  - Excavating creeks by machine
  - Facilitating marsh migration
  - Increasing surface elevation

# Gooseneck Cove adaptive management

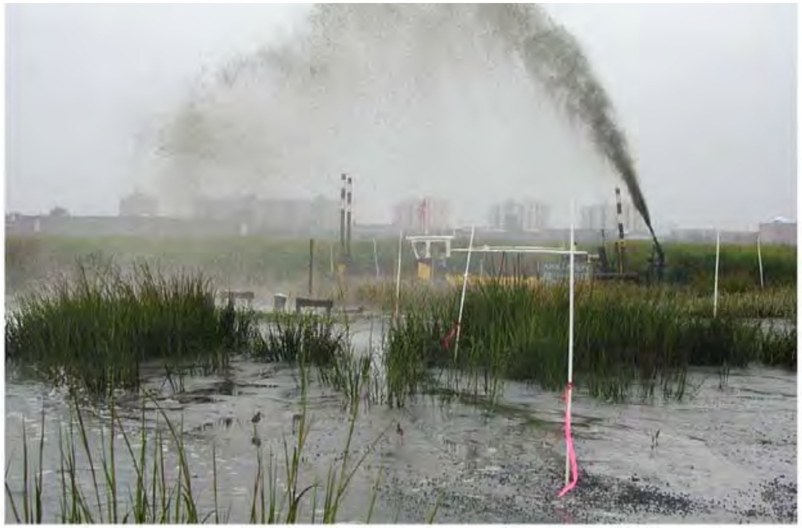


# Round Marsh, Jamestown

# Marsh migration


# NPS Thin-Layer Sediment Spraying Pilot

## Jamaica Bay, NY

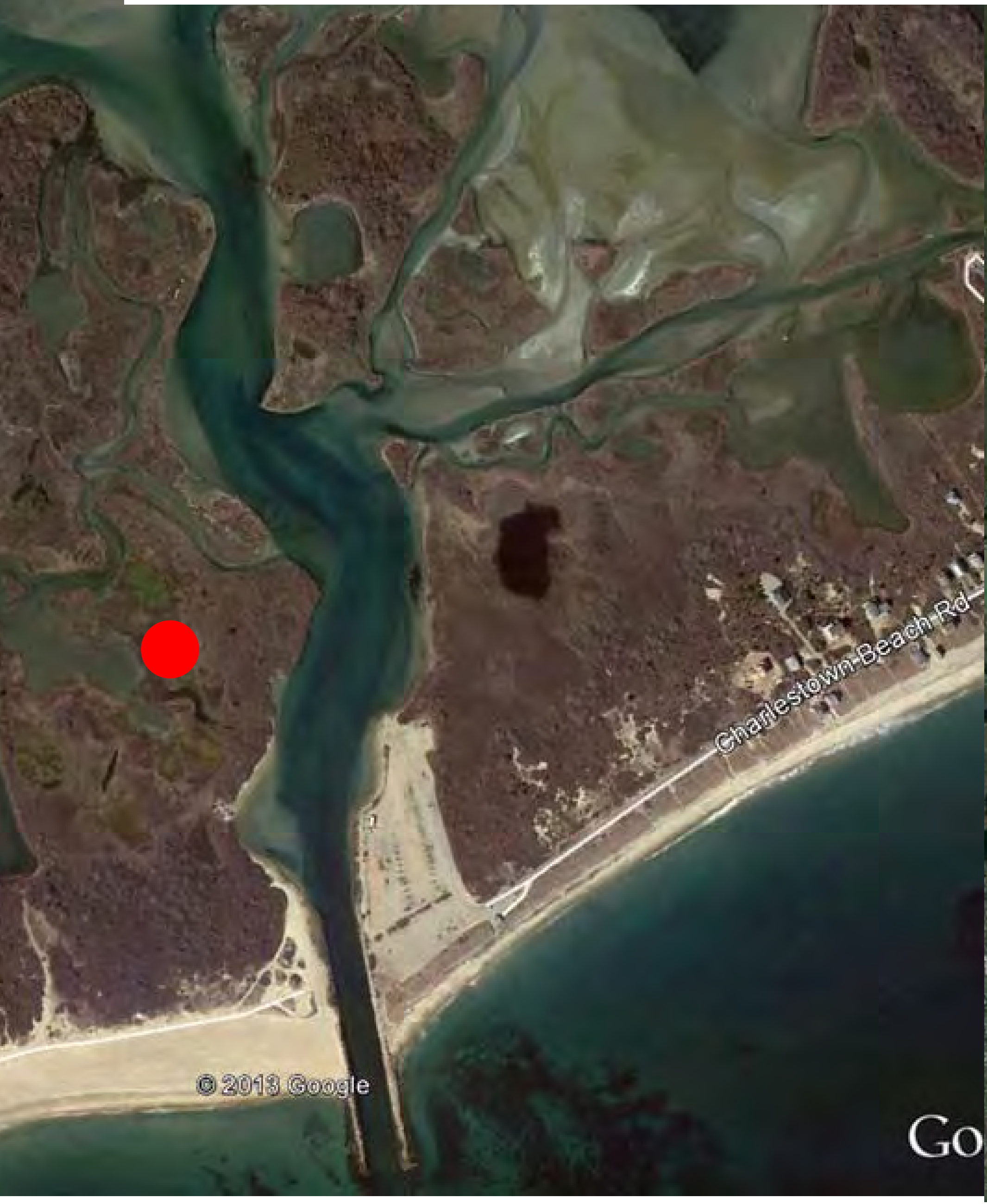


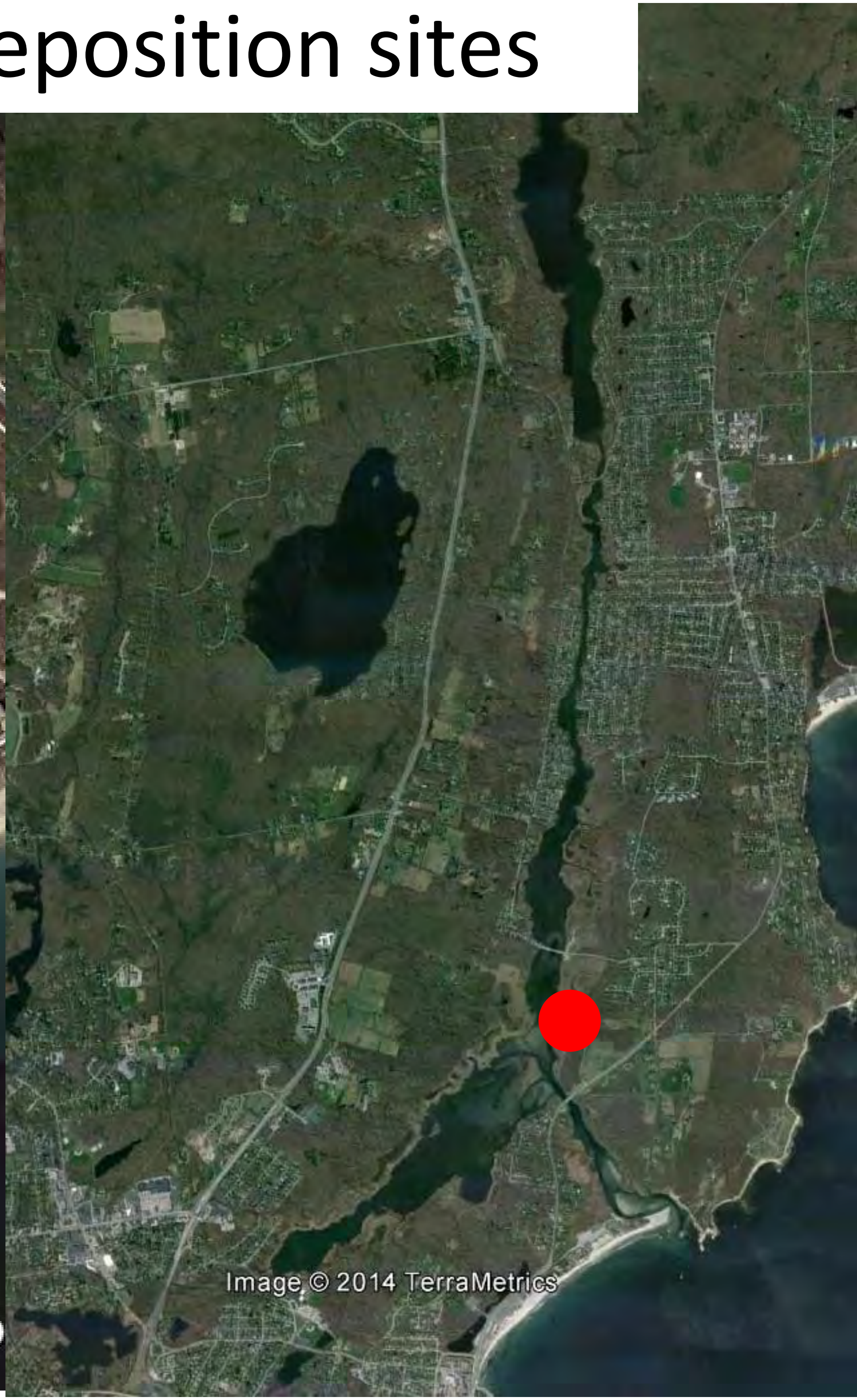
COVER PHOTO  Photo Credit: D. R. Cahoon


# Delaware Bay Thin-Layer Spraying

## Pepper Creek, DE

# Potential thin layer deposition sites



# Next Steps

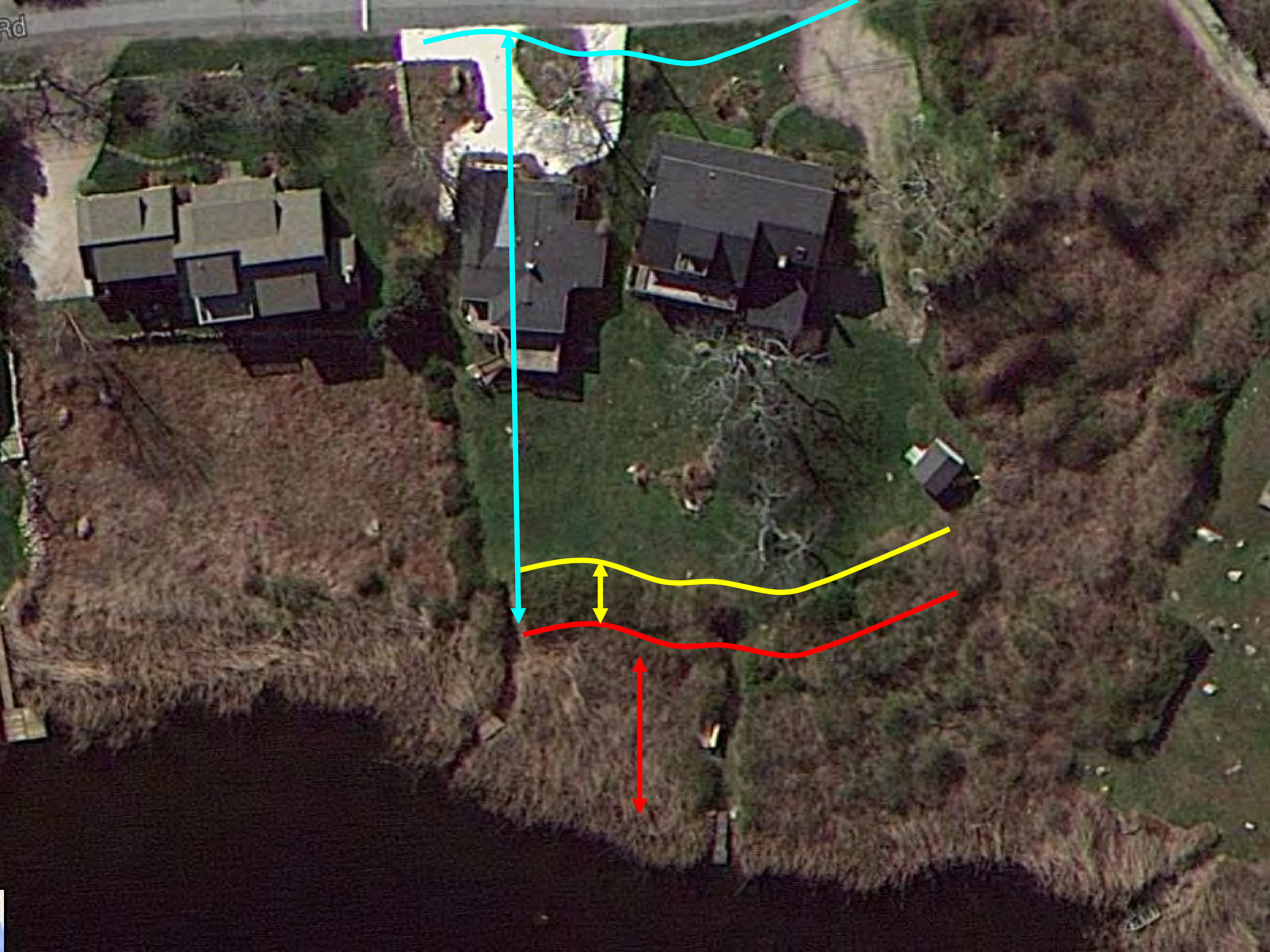
- Identify new sites for adaptation
- Assess and compare results of runnel and creek excavation between different marshes
- Design and implement thin layer deposition
- Implement runnel work at additional sites



# Sea Level Rise Impacts to Salt Marshes: Implications for Coastal Zone Management in RI

Caitlin Chaffee
Coastal Policy Analyst
RI Coastal Resources Management Council
www.crmc.ri.gov

COASTAL RESOURCES MANAGEMENT COUNCIL


Rd


Phragmites

# Impediments to Coastal Marsh Migration

# Regulatory Considerations

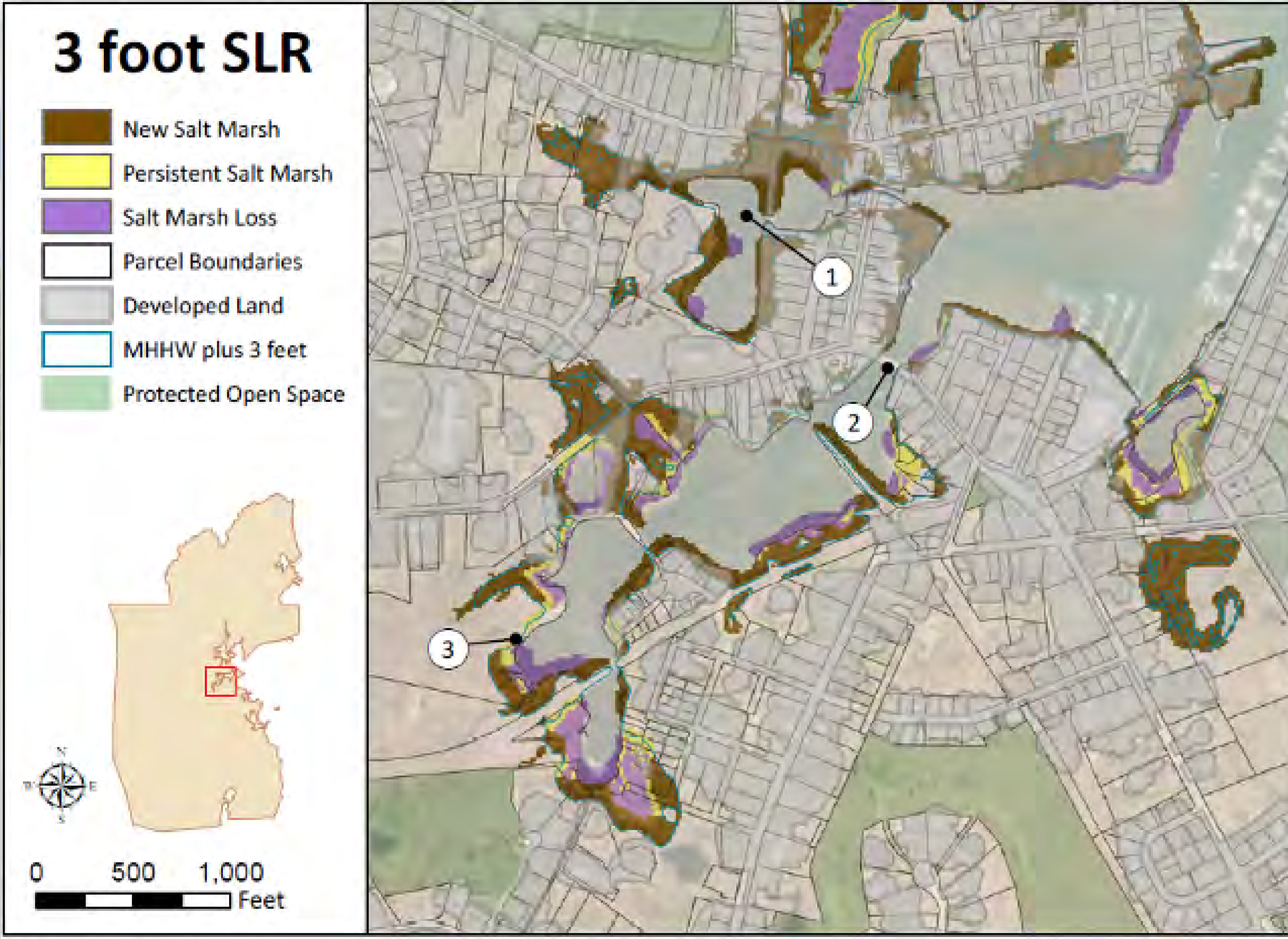
- How can we adapt our regulatory program to better accommodate wetland migration (Setbacks, Buffers, Variances, Water Types, Coastal Wetlands, Mitigation, Shoreline Structures) ?
- How should we respond to requests to manage vegetation in the coastal zone?
- What is the best policy for management of *Phragmites* in the face of SLR?

# Policy and Planning

- Section 145
- Shoreline Change Special Area Management Plan
- Where do salt marshes fit in?

# We’re SLAMMin’!

- Modeling coastal wetland change at 1, 3, and 5 foot SLR scenarios
- Estimating future wetland loss
- Identifying barriers to wetland migration and opportunities for adaptation
- Presenting information to coastal municipalities


3 foot SLR
New Salt Marsh
Persistent Salt Marsh
Salt Marsh Loss
Parcel Boundaries
Developed Land
MHHW plus 3 feet
Protected Open Space
0
500
1,000
Feet
1
2
3

# **S**ea **L**evel **A**ffecting **M**arshes **M**odel

- Predicts significant loss at 3’ and 5’ SLR scenarios of salt marsh and brackish marsh
- Large gains in “transitional marsh” for a net gain in wetlands
- What is the real potential for migration, and what will migration look like?


Photo: Save The Bay

Photo: Save The Bay

# Shoreline Adaptation

- Identifying public infrastructure that is currently at risk from erosion, SLR
- Designing “soft” solutions (re-grading, removal, retreat, replanting, reinforcement with “soft” materials)
- Working with municipalities to implement demonstration projects

Photos: Save The Bay

# State Coastal Wetland Restoration Strategy

- Use results of assessment efforts to prioritize restoration approaches and projects
  - RISMA
  - NBNERR Sentinel Site monitoring and Spectral Image Analysis
  - SLAMM
  - Others
- Include feedback from researchers, managers and other stakeholders (this means <u>YOU</u>!)

# Considerations for Restoration Strategy

- How do we adopt new and emerging techniques? What are the regulatory issues?
- How do we consider other stressors (erosion, nutrients, invasive species, hydrologic alterations) alongside SLR?
- How do we incorporate SLR into “traditional” restoration projects?
- How do we improve communication between researchers and managers?
- How can we best measure cost/benefits?
- What additional information is needed to set goals and priorities?

# Questions?

**www.crmc.ri.gov**

Caitlin Chaffee
cchaffee@crmc.ri.gov

CRMC
Coastal Resources Management Council

Photo: P. Paton

# Long Island Sound
# Tidal Wetland Loss Workshop
# June 24 & 25, 2003
# Stony Brook, N.Y.

*Workshop Proceedings and Recommendations to the Management Committee of the Long Island Sound Study*

LONG ISLAND SOUND STUDY

*A Partnership To Restore and Protect The Sound*

## *Acknowledgements*

This workshop was made possible by a grant from the USEPA Long Island Sound Study, generous sponsorship from New York Sea Grant, the Marine Sciences Research Center of Stony Brook University, and the enthusiastic participation of all in attendance.

The success of this workshop is a testament to the dedicated professionals who gave of their time and expertise during this workshop to protect the living resources of Long Island Sound.

## *Table of Contents*

## *Introduction*

In 1999, the New York State Department of Environmental Conservation staff identified significant losses of intertidal marshes in Jamaica Bay, Queens, N.Y. These losses were occurring in spite of protective wetlands legislation and with no readily identifiable cause. A trend analysis conducted using aerial photography and historical survey charts indicated a fluctuating, but generally stable, intertidal marsh acreage between 1857 and 1924. Between 1924 and 1974 large losses were documented due to both direct dredging and filling related to land and port development, but losses averaging 10 acres per year had occurred for other reasons. The trend analysis further revealed an accelerating loss rate from 1974 to the present that appears to be unrelated to direct dredging and filling.

Department staff also began to document similar intertidal marsh losses in other New York estuaries. In particular, marshes in Long Island Sound appeared to be suffering from the same mysterious processes as those in Jamaica Bay. Staff at the Connecticut Department of Environmental Protection also observed apparent losses in the tidal portions of the rivers that drain to the Sound. This issue was brought to the attention of the Long Island Sound Study (LISS) Management Committee for further action. Funds were awarded to New York State to convene a workshop of experts in the field to address this problem.

## *The Workshop Format*

The workshop was held on June 24 and 25, 2003 in Stony Brook, New York. Approximately 60 scientists and managers from the Long Island Sound region and from other parts of the country were invited to participate in the two-day forum. Approximately 50 people accepted the invitation and participated in the workshop. A list of attendees may be found in Appendix A.

The goal of the workshop was to create a strategy to address the issue of unexplained tidal wetland loss in the Sound that included:

- An assessment of current understanding of wetland loss processes
- A research agenda for Long Island Sound marshes
- Monitoring recommendations
- Management recommendations
- Restoration recommendations

During day one of the workshop, invited speakers presented research germane to the discussion of the issue of wetland loss in Long Island Sound. A list of speakers and the titles of their presentations appears below. Abstracts of the presentations and copies of the slides shown are attached in Appendix B.

| | |
|---|---|
| **Fred Mushacke** : | Wetland Loss Trends in Long Island Sound NY |
| **Ellen Hartig** : | Salt Marsh Submergence: A Case Study in WLIS |
| **Greg Edinger** : | EPA Long Island Reference Wetland Project 1997 - 2000 |
| **Ron Rozsa** : | Relative Sea Level Rise, Surface Accretion and Vegetation Change on Eastern LI Sound Salt Marshes |

| | |
|---|---|
| **Scott Warren:** | Relative Sea Level Rise, Surface Accretion and Vegetative Change on Eastern Long Island Sound Salt Marshes |
| **Shimon Anisfeld** : | Tidal Wetland Loss in the Quinnipiac River Estuary |
| **Johan Varekamp** : | Marsh Accretion under different rates of RSLR over the Last 1000 Years |
| **Rich Orson** : | The Paleorecord: What Historic Development during the Last Thousand Years may Mean to Present Day Wetland Losses |
| **Alex Kolker** : | Sedimentation Patterns in the Nissequogue River |
| **Bob Wilson** : | Changes in Harbor Hydrodynamics resulting from alterations in Wetland Morphology |
| **Vivien Gornitz** : | Sea Level Rise, Storms and Coastal Wetlands: A Regional Overview |

Donald Cahoon of the U.S. Geological Survey gave a keynote presentation at lunch titled "Wetland Sediment Elevation Dynamics and Sea-Level Rise." A field trip to nearby Youngs Island in Stony Brook Harbor allowed participants to observe, first hand, losses typical of many areas in Long Island Sound. Appendix C contains photos of the field trip site and the analysis of losses in vegetated wetlands since 1974. Following the field trip a keynote address was given at dinner by R. Eugene Turner of Louisiana State University, titled "Disrobing at Many Shorelines." Extensive discussion was generated by the talks and field trip that carried into the next day.

## *Breakout Sessions*

Day two of the workshop consisted of breakout sessions. The day was divided into three breakout sessions and a final plenary session. Each breakout session was divided into four individual groups, two in each of two discipline areas. Two groups discussed physical and hydrological factors, while two groups discussed geochemical and biological factors. Each group had a discussion leader and a student rapporteur to assist in capturing the discussion and preparing it for presentation at the final plenary session. Session one was a discussion of controls, stresses, and forcing functions of the tidal wetlands and loss mechanisms. Session two discussed the responses and impacts in the marsh to the stressors and controls identified in the first session. Session three used the findings of the first two sessions to generate recommendations for a research agenda, a monitoring program, restoration actions, and management of the issue. All of the discussion groups came together at the end of the day in a final plenary session to present the results of their discussions. The following sections represent the recommendations and consensus of the participants on moving forward in dealing with this important issue.

## *Breakout Session 1: Controls, Stresses, and Forcing Functions in Marsh Systems*

The first breakout session discussion on forcing functions, stresses, and controls of marsh health generated lists of many potential factors in the process of marsh loss. Sediment budget and relative sea level rise (RSLR) data indicate that marshes in the Sound and nearby systems are theoretically receiving enough suspended material to allow marsh accretion to keep pace with RSLR. This has been the case in marshes in the Sound for centuries. Why it has begun to shift in the last thirty years is unknown. Discussions among scientists from the physical and biological disciplines generated a sense of uncertainty about how the physical and biological components of the marshes are interacting and what effect anthropogenic stressors are having on the marsh system.

Perhaps most importantly, the participants highlighted the need to gather baseline information on marsh health and spatial distribution on a regular schedule. This baseline data gathering should be done regardless of any specific research study, and would most appropriately be conducted by the natural resource management agencies in the Sound. The lack of these data is currently hampering efforts to determine the causes of the widespread marsh losses observed in the Sound. Understanding the causes will enable managers to define a clear course of action to prevent further loss.

Summaries of the discussions by individual breakout groups follow.

### Biological and Chemical Group 1:

The group began by listing the primary stressors of marsh systems. These were nitrates, sulfides, salinity, pollutants, diseases, boat wakes, and morphological features like bulkheads. The pollutants of particular concern are herbicides, lime, creosote, and MBTE. Multiple stressors are present at most sites in the Sound and may be producing synergistic effects on the marsh. Some stressors present in the estuary at large may be exacerbated by local sources such as storm water outfalls.

Data gaps concerning the biogeochemistry of marshes in LIS, data on the marsh sediment elevations and plant composition, and marsh species variant strains hinder efforts to define the causes and effects of the stressors on the system. There is a need to identify the constituents and location of the turbidity in rivers draining to the Sound and how they have changed over time. Changes in the turbidity maximum in river systems may have led to changes in the sediment and pollutant loading to marshes.

Forcing functions were identified by the group as relative sea level rise, thermal and climate changes, increased variability of hydrological conditions, dredging, storms, and human population in the coastal zone. The thermal and climate changes can affect ambient $CO_2$ concentrations and increase the ice scour activity during winter. Climate changes may also increase the frequency or severity of storms and wave action.

Discussion followed on the formulation of a hypothesis that changes in the input of total nitrogen changes the sediment structure in marshes. The postulated chain of events begins with increased nitrate causing increased above-ground plant growth and relative reduction in below-ground biomass, this in turn causes peat decomposition through increased aeration of the peat, resulting in a less stable marsh. The resulting stressed marsh is more vulnerable to further stresses and forcing functions. There was also discussion about the potential for increases in nitrogen and phosphorus loading to the marsh to change the microbial activity in marsh sediments.

The importance of defining the process of marsh loss and the reality of what is happening in the marshes was also discussed. Important points that were raised included the possibility of cover type conversions from high marsh to low marsh, or from *Phragmites* to high marsh. These seemingly benign or even desirable changes could be signaling early problems in the marsh system. The extent of marsh break-up, as well as area of marsh accretion, needs to be determined through aerial photo interpretation to create an overall picture of the extent of the loss.

A final point of discussion involved the impacts of navigational dredging on nearby marshes. It is hypothesized that dredging may result in reduced inorganic material being deposited on marshes. Investigations into the importance of the inorganic components of marsh sediments are needed.

### Biological and Chemical Group 2:

The group began with a general discussion of the full extent and implications of the marsh losses documented so far. Information on the spatial and temporal scale of the problem, as well as the particular characteristics of affected vs. unaffected marshes is critical to defining the problem. Measurements of hydroperiod, organic vs. inorganic soil components, micronutrient content, and basic parameters of healthy plant conditions are necessary to begin analysis of the problem. The detection of anthropogenic factors may lead to identification of reversible losses. The consistency of development in the coastal zone between 1940 and 2003 makes a good case for anthropogenic causes. Based on information gathered in the field so far, maintaining the remaining marshes is vital since revegetation of fragmented areas does not occur even in the presence of available seed banks.

The group went on to outline the controls and stresses they believe are affecting Long Island Sound marshes. The biotic factors include leaf miners and other insects, geese, crabs, burrowing action by fiddler crabs, periwinkle snails, and epiphytic organisms. Hydrologic effects include fresh water pulses, climate change, ground water quality, ground water withdrawal, and pore water characteristics. Sediment characteristics such as grain size, species composition of the peat, the bulk density of sediments, the inorganic vs. organic volume, sediment boundaries and discontinuities are all important influences on the health of the marsh.

The group discussed how biogeochemical processes in the marsh become disrupted and, in turn, cause degradation of the marsh. The majority of these processes are tied to eutrophication of the marshes and waters of the surrounding estuary. Changes in nutrient composition and nutrient levels in turn cause changes in the allocation of resources to above and below ground biomass of marsh plants, sulfite reduction in marsh plants, changes in microbial action in marsh soils, and altered denitrification. Eutrophication may also play a role in changes to the marsh epiphyte community, changing the shading effects and fouling organisms present. Changes in nutrient type and abundance also affect the above and below-ground biomass of the marsh by changing the root to shoot ratio. Eutrophication can increase biomass of macrophyte species, especially *Ulva lactuca*. Dense mats of *Ulva* become stranded on the marsh surface and can kill *Spartina alterniflora*. This can also happen with dense rafts of *Phragmites australis* stems deposited on the marsh surface.

Climatic changes in the estuary were discussed. The increase in carbon dioxide content of the atmosphere may be driving changes in the plant community. Climate changes may also be influencing the amount of ice formation and damage to the marsh during winter months.

### Physical and Hydrological Group 1:

The group began by discussing the factors that control a marsh at equilibrium and what stresses upset that equilibrium. Sea level rise controls the marsh in that relative sea level rise at an appropriate rate facilitates marsh accretion, but relative sea level rise at too great a rate causes the marsh to drown. Relative sea level rise and marsh morphology drive tidal range and hydroperiod on the marshes. Sedimentation rates, bed load, relative organic and inorganic sediment fractions, and resuspension rates also influence marsh accretion.

The group then discussed the data needed to determine the root causes of marsh loss. Sedimentation characteristics need to be investigated to fully understand the implications of relative sea level rise on the marshes. Measurements of hydroperiod on the marshes provide critical information for determining the mechanisms of marsh breakup. Subsidence is an additional component that must be examined to understand the driving process of marsh loss. Both surface and ground water inflow must be examined for their impact on subsidence and marsh vegetation. Currents, wave energy, and ice scour are all erosive effects on the marsh.

Geomorphology of marshes across the Sound, including depth of peat, size of the marsh, and shape of the marsh and basin should be compared for common characteristics of fragmenting marshes. Examination of seasonal cycles of tides, variability caused by larger climate processes such as the North Atlantic Oscillation, and changes in ocean circulation need to be examined to separate seasonal variation from overall changes over time. Looking at human alterations of the system over time is also important, although the group recognized that loss is too wide spread to blame on any single type of land use. This is further supported by the documentation of losses in sub-estuaries with relatively little development.

The group discussed the importance of changes in marsh zonation as an indicator of larger changes in the marsh. Biotic factors like bioturbation, biocementation, and grazing by geese may all factor into the efficiency of the marsh in trapping sediments.

### Physical and Hydrological Group 2:

The group began by identifying sea level, sediment supply, subsurface processes, and subsidence as forcing functions. The individual mechanisms of subsidence must be identified in fragmenting marshes. These are subsurface withdrawal of water and natural gas, compaction by ice, storm surges, and surface deposition both by sediment transport and dredge spoils.

The accumulation rate in the marsh is comprised of both organic and inorganic accretion. The factors influencing organic accumulation were identified as above ground biomass, root biomass, nutrients, below-ground hydroperiod and ground water inputs, surface and sub-surface drainage, species composition of the marsh flora, and salinity. Factors influencing inorganic accretion are hydroperiod, surrounding land use and level of development in the watershed, sediment supply, and storm frequency and severity. Erosion acts as a counterbalance to all of these and is influenced by the position of the marsh in the estuary. Physical location determines the wave action, tidal currents, and amount of bank slumping that occurs in a marsh. Human activity alters several of these factors through dredging, land use changes, and on a larger scale, climate change. Marsh drainage, in particular, has been subject to human intervention. Installation of tide gates, ditches, dikes, and Open Marsh Water Management actions have altered the tidal prism and natural drainage dynamics of marshes. Non-human biotic factors such as animal grazing, bioturbation and tunneling, wrack deposition, and decomposer community alter the floristic characteristics of the marsh.

The group summarized their findings about controls in the system and the effect each one has on marshes in Long Island Sound. The conclusions are presented in descending order of importance as determined by the group.

The most important factor according to his group is relative sea level rise and its role in waterlogging marsh substrates to cause submergence. While cause and effect may not be a singular determination in the case of marsh loss, this one factor can be shown to have a direct relationship in the marshes.

The overall hydrology of the site was next in importance due to its control over accretion, subsidence, erosion, below ground biomass accumulation, and the structure of the biotic community. Examination of the underlying geomorphology of marshes and local tide information is crucial to fully understanding the role of hydrology in the loss of marshes.

Anthropogenic effects control the nutrient and contaminant inputs to the marsh, sediment distribution in the estuary, alteration of the individual hydrology and hydroperiod in marshes, disruption of the food web in the estuaries, and exacerbation of wave action on the marshes by boats and personal watercraft.

Closely allied with the hydrology of the site is the geomorphology and landscape position of the marsh in the estuary. This, in turn, influences the accretion and substrate composition of the marsh.

Finally, climate influences the primary production in the marsh and surrounding waters, the rate of decomposition in the marsh, sediment supply, salinity, and storm frequency and intensity.

## *Breakout Session 2: Responses and Impacts*

The second set of breakout group discussions focused on the responses of marshes in Long Island Sound to the controls, stresses, and forcing functions identified in the first breakout session. Participants were given the option to remain in the same discussion group or to change to a different group. As with the first session there were two groups discussing biological and chemical responses, and two groups discussing physical and hydrological responses. All the groups approached the second session by proposing hypotheses to be tested and posing questions about the process of marsh loss.

### Biological and Chemical Group 1:

Discussion began with questions about the impacts of eutrophication on the sediment structure and microbial activity in marshes. Nutrients are related to abundance of eelgrass beds in the estuary. Managers have observed larger eelgrass beds near healthier marshes. The conversion of eelgrass to macroalgal beds may be an indicator or feedback mechanism for marsh loss. The loss of eelgrass in the 1930s may be a first step in degradation followed by the currently observed losses of vegetated wetland. The group formulated the hypothesis that increased total nitrogen input modifies the sediment structure in marshes. Increased phosphorous may also play a role.

The idea of sediment starvation was discussed in the context of changes in dredged material management. Dredged material was historically placed on wetlands, thereby retaining the sediments in the system. Now most dredged material is disposed of upland or offshore, potentially creating a sediment sink in the wetland. Investigating correlations between dredging activity near wetlands and extent of marsh breakup in that area should be performed. This needs to be tied to investigations of relatively intact marsh systems like the back barrier area of Fire Island near the Carmens River. The river still has natural flow patterns and the barrier beach shows some new marsh formation. The group cautioned, however, that gains of wetland in less urban areas do not necessarily balance or explain losses in more urban areas. This further highlights the need for a trend analysis of marsh loss system-wide that can be correlated to the perceived stressors in the system.

Invasive species are of great concern because little is known about their impacts on the marsh system. Asian shore crabs may affect the marsh structure. Native crabs are known to perforate the peat and perhaps boost productivity of marsh plants. Resident Canada geese create stress on the marsh by eating the young shoots of *Spartina* and depleting below-ground biomass by forcing regrowth of leaves. This could be significant when coupled with boat and personal watercraft wake erosion in marsh channels.

There is need to study the potential impacts of chemicals in the marsh system. Sewage, fertilizers, heavy metals, MBTE, petroleum hydrocarbons, and pesticides may have altered the system in subtle ways. They have great potential for disrupting the food web in marshes as in the effects of DDT on green fly larvae. Comparison of least disturbed marshes to those experiencing fragmentation is necessary to observe these effects.

## Biological and Chemical Group 2:

The group began their discussions in this session by examining the role of sulfide in marsh health. The group hypothesized that changes in sulfide concentrations in the marsh change denitrification rates and patterns. Examination of the extant literature is necessary to determine what the maximum levels of sulfide should be in a northeastern marsh and examine methodology for field measurements of sulfide. Documenting variations in sulfide across marshes may be a key to determining mechanisms of marsh fragmentation. However, sulfides are just a reflection of ambient conditions, so care must be taken to identify the underlying drivers of sulfide in the marsh. Examination of air deposition, ground water input, and surface runoff contributions of sulfide is an integral part of marsh characterization of sulfide processes.

Boat wake as a degrading force in marshes was discussed in the context of boat speed, tide stage, and distance from the marsh. Development of modeling data will allow managers to demonstrate a clear negative effect on marshes if one exists. The data will also generate guidance on potential buffer zones.

Observations of documented marsh fragmentation indicate that there are some remaining areas in the system that are healthy or improving. Examination of this phenomenon within marshes and across marshes may shed some light on the fragmentation characteristics. The question of whether all the degradation is occurring at a similar elevation or position within marshes is fundamental to understanding the sequence and mechanics of marsh loss.

This group discussed Canada geese as well as other grazing waterfowl and their effect on marsh fragmentation. Brant, swans, and snow geese are all potential grazers on the marsh surface along with Canada geese.

The macronutrient requirements and ideals of *Spartina* and other marsh vegetation should be culled from the literature. Where data gaps exist, test plot experiments in the field should be conducted. This will allow better understanding of the implications of chronically eutrophic waters on the marshes. The group hypothesized that excessive nutrient species may be causing *Spartina alterniflora* to shift biomass production to vegetative growth rather than seed production. Investigations into rhizomatic growth versus sexual reproduction will shed light on this issue as well.

### Physical and Hydrological Group 1:

The group began the session by discussing the effects of sediment supply on marshes. Determining what changes may have occurred in sediment supply over time is key to understanding what may be causing the marshes to drown. If marshes are unable to keep pace with relative sea level rise, then the reason for this must be determined. Sediment availability should be measured and the opportunity for sediment deposition onto the marsh must be determined. The sedimentary fractions of organic versus inorganic particles may have changed. The effects of this change are unknown, as is the separate importance of each fraction. These roles may change across marsh zones, as from high marsh to low marsh.

Determining the sequence and extent of loss is key to understanding the whole problem. Chronological examination of aerial photography sets and ground mapping of gradients from east to west and low marsh to high marsh should yield common characteristics of healthy and degraded marshes. Documenting landward migration of high marsh is important to help separate sea level rise and other hydroperiod effects like dredging and inlet alteration. Microtopography patterns in the marsh interior seem to be significant in the early stages of marsh break up. Very small depressions are the first areas to show stress. Altered drainage through ditching and ditch infilling seem to conflict with hypotheses about relative sea level rise, although the real effects of ditching may be on the fresh water flows and overall water table of the marsh. Changes in the marsh salinity have traditionally followed ditching and could be creating salt stress on the plants.

### Physical and Hydrological Group 2:

The group began with a discussion of the time scale involved in the application of stressors and the marsh response. Below ground biomass and subsidence of the marshes is a critical point of understanding that no one is investigating in the Long Island Sound system. The landscape location of the marshes needs to be correlated with the loss patterns to determine common geomorphological attributes of fragmenting marshes.

Marsh submergence occurs in response to complex processes like erosion, increased water area, substrate decomposition, hydrologic changes due to ditching, diking, and dredging, changes in sediment supply. The plants in the marsh may respond to subtly different effects of erosion, increased water area, and disruption of the wetting and drying regime. Development of a conceptual model of Long Island Sound marshes may assist in determining the relative magnitude of any one stressor. The group felt that stressors were leading to a cascade effect within fragmenting marshes.

## *Panel Recommendations*

One overriding comment from the participants in the workgroups was that the causative factors in marsh loss are largely unknown, both in Long Island Sound and elsewhere in the country. The participants surmised that multiple factors are likely to be at work in the losses observed thus far. It is difficult to determine without careful additional investigations which degrading factors are causative, which are exacerbating the degradation, and which are symptomatic of the existing degradation process. Comparative studies of affected and unaffected marshes are critical to understanding the process of loss. It is unclear at this time what role landscape location and geomorphology of individual marsh systems play in the degradation of the marsh vegetation. The panel also felt strongly about the need for regional collaboration and coordination of research, monitoring, restoration, and management activities. The panel had several specific recommendations in each of the categories.

### Research recommendations:

1. Create a conceptual model of the salt marsh system in the Sound. The creation of a conceptual model will aid in the definition of causes and effects of degrading forces on the marsh. The specific components of the model should include:
    - Identification of chemical processes in the marsh and their role in plant health and peat accumulation.
    - Identification of biological processes from bacterial activity to vertebrate gazing. Correlation of biotic data on waterfowl populations, snails, crabs, mussels, insects, molds, and parasites to marsh health whenever possible.
    - Characterization of both above and below-ground biomass and the relationship between the two and marsh health.
    - Characterization of the substrate properties in marshes, defining the organic and inorganic constituents and their relative importance in marsh accretion.
    - Identification of potential system stressors and threshold values for negative effects including:
        - chemical pollutants like MBTE, DDT, herbicides, petroleum, and others
        - physical processes like boat wakes, dredging, ditching and ditch plugging
        - hydrological factors like ground water withdrawal, alteration of surface flows through storm water redirection, changes in local hydroperiod due to bathymetric changes and shoreline hardening.

2. Conduct wide-scale investigations across gradients of several kinds. These types of comparative evaluations will help characterize what role physical location or local conditions are playing in the sequence of marsh loss. Investigations should include but not be limited to:
    - differing tidal range;
    - marshes affected vs. unaffected by loss;
    - differing salinity regimes;
    - differing marsh geomorphology, e.g. river basins vs. back barrier marshes;
    - presence or absence of alterations such as ditching and dredging; and
    - sulfate reduction processes should be detailed along with pH and sulfur profiles across marshes.

3. Conduct manipulative experiments on tidal wetlands to identify limitations in the existing system. These data can be used to validate and refine the conceptual model. Experiments should be conducted *in situ* as well as in the laboratory. Specific experiments should include:
    - manipulation of nutrient regimes, including organic and inorganic inputs of phosphorous and nitrogen;
    - manipulation of biotic communities;
    - transplantation experiments with *Spartina*; and
    - manipulation of sedimentation regimes and resultant effect on marsh health.

4. Conduct assessments of anthropogenic effects on marshes in the Sound. These results will facilitate further meaningful management recommendations to protect long term marsh health and stability. These assessments should include:
    - analysis of categories of regulated activities occurring adjacent to marshes and the relative health of those marshes;
    - human population and land use changes over time as correlated to marsh formation and loss;
    - physical studies of the erosive properties of boat and personal watercraft wakes on marsh peat; and
    - effects of proximal dredging on stability of and sediment transport to marsh islands and fringing marshes.

5. Conduct studies of marsh accretion rates to better understand the local reaction of marshes to relative sea level rise. These assessments should include investigations into the changes in sediment budgets and supply on a time scale of not less than 300 years. The Foraminifera communities of sediments and radioisotopes should be characterized as markers of change in the system. The Foraminifera communities are indicators of climate changes and the radioisotopes are date and source indicators in the sediment horizon. Changes in sediment properties over time should be analyzed.

## Monitoring Recommendations:

The panel strongly urged that the Long Island Sound Study initiate and maintain responsibility for basic annual monitoring of marshes around Long Island Sound. There is a need for consistent baseline monitoring irrespective of any one research investigation. The LISS needs to establish monitoring protocols and create an accessible data set for the research and management community.

1. Develop a regional marsh sampling framework coordinated by the Long Island Sound Study. The sampling should be stratified and examine geomorphology, stressor ranges, biotic condition and community, hydrology, elevation trends and accretion rates. As part of this framework, a Sound-wide system of reference marshes needs to be established for long-term study. The reference sites should include both healthy and degraded marshes, within-marsh variation measurements, tide gauges, permanent plots and transects, marker horizons, and Surface Elevation Tables. These basic investigations as critical to understanding and addressing the mechanisms of marsh loss in Long Island Sound.

2. Define the loss of marshes on both a temporal and spatial scale. The marshes in the Sound need to be re-inventoried immediately. Inventory should be conducted on a regular schedule of no less than every five years. Longer intervals are significantly less useful in defining system processes. Supplemental oblique angle videography should be taken annually to depict the elevation of marshes. Additional photography should be obtained following major storm events.

3. Use inventory information to conduct a comparative trends analysis from all available data sources. Use this information to characterize the pattern of wetland loss in as much detail as possible. Describe recurrent patterns in fragmenting and healthy marshes.

### Restoration Recommendations:

The panel recommended that LISS continue funding restoration projects under the Habitat Restoration Initiative. LISS should continue act as a coordinating body for regional restoration efforts and seek new data collection on restoration project success and failure to use in the overall management decision making process.

1. Continue restoration treatments using an adaptive management strategy. Include analysis of success in marshes lost to fragmentation versus marshes lost to other more “natural” processes like sand shifts at inlets. Restoration projects should make use of coconut fiber products as wave breaks and artificial peat to combat erosion and subsidence. Dredged material should be sought to raise elevations on fragmented marshes. All projects need consistent monitoring and course corrections.

### Management Recommendations:

1. Conduct a full literature search of Long Island Sound research. Use the results to determine optimal requirements for plants in LIS marshes to be incorporated into the conceptual model recommended above. Analyze what gaps exist in the data and use to prioritize further research.
2. The LISS should prioritize stable funding for marsh monitoring as an ongoing work item.
3. The LISS should continue in its coordination role among agencies and researchers to facilitate effective management of marsh loss in the Sound.
4. The LISS should continue in its coordination role among agencies and researchers to facilitate needed research as outlined above. This coordination role should extend to making data readily available to researchers and managers.
5. The LISS should continue to display leadership in bringing attention to the important issue of marsh loss, and educate the public, research community, lawmakers, and natural resource agencies about the issue both locally and on national level.
6. Monitor ongoing projects to ensure that restoration and management actions such as ditch maintenance, Open Marsh Water Management, and *Phragmites* eradication efforts are not inadvertently harming marshes over the long term.
7. Use ongoing nitrogen reduction planning to target nitrogen removal at localized sources impacting marshes.

8. Advocate "hands on" management and maintenance of marshes in public ownership. It is clearly inadequate to simply protect marshlands through acquisition.
9. Investigate policy recommendations to accommodate landward retreat of marshes. This will likely require some means of addressing shoreline hardening.

## *Next Steps*

The panel strongly recommended a follow up forum on this topic. They advocated broader inclusion of regional and national researchers and managers. They felt that the interplay between researchers and managers in different disciplines was particularly useful.

U.S. Fish & Wildlife Service

# SALT MARSH TRENDS IN SELECTED ESTUARIES OF SOUTHWESTERN CONNECTICUT

**APRIL 2006**

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Salt Marsh Trends in Selected Estuaries of Southwestern Connecticut

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## INTRODUCTION

Recent investigations have shown that rising sea levels are having a significant impact on tidal wetlands in many areas of the United States. Higher water levels are inundating lower portions of these marshes and converting them to tidal flats, while portions of the high marsh are being converted to low marsh. The importance of coastal marshes to marine and estuarine ecosystems and migratory waterfowl is widely recognized. Because of these and other values (e.g., storm surge detention), most coastal states have adopted specific legislation to protect these highly valued natural resources. The State of Connecticut was among the first states to pass such legislation and has been protecting its tidal wetlands since 1970. While this law has virtually eliminated the once-widespread dredging and filling of tidal wetlands, nature's forces (i.e., rising sea level) continues to impact these wetlands.

The Long Island Studies (LIS) Program of the Connecticut Department of Environmental Protection (DEP) has noticed the habitat changes indicative of sea-level rise in many coastal wetlands. In 2005, DEP provided funds to the U.S. Fish and Wildlife Service to conduct a trends analysis of selected salt marshes along the southwestern coast of the state to document habitat changes. The Natural Resources Assessment Group (NRAG) at University of Massachusetts provides technical support to the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) Program and assisted with this trends analysis project.

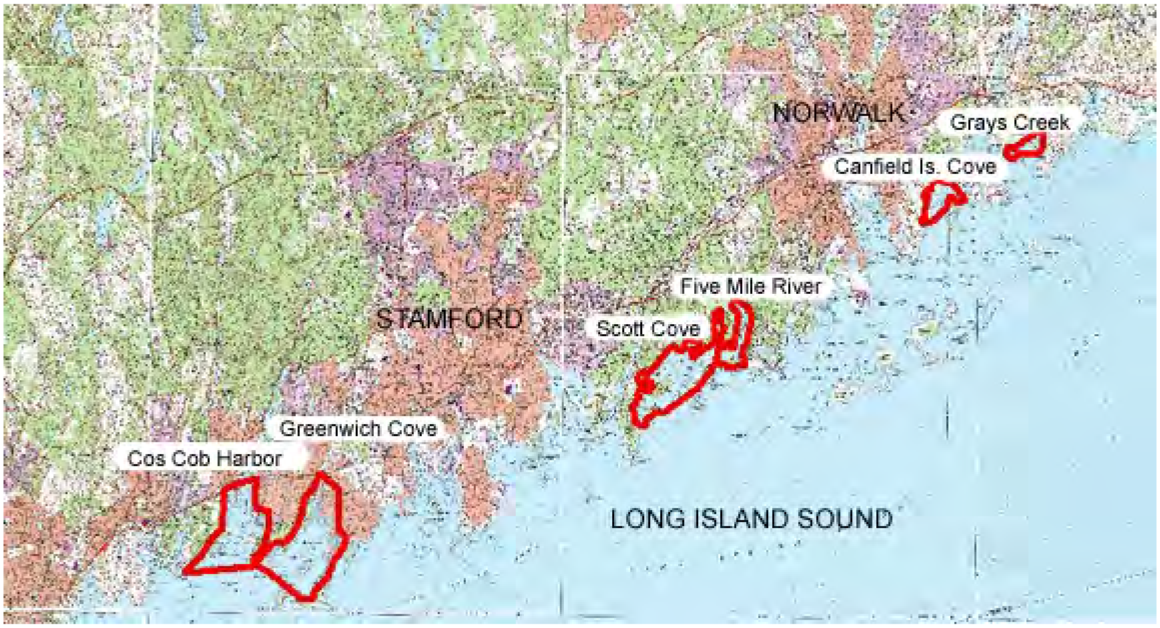
### Study Objectives

To document changes in marsh vegetation zones (low marsh and high marsh) in six salt marsh areas in southwestern Connecticut since 1974. The following time periods would be evaluated: 1) 1974-1981, 2) 1981-1986, 3) 1986-1990, 4) 1990-1995, 5) 1995-2000, and 6) 2000-2004. Photointerpretation of vegetation changes would document the total changes between intervals and over the past quarter century as well as identify any differences in the rate of change during the entire study period.

### Study Areas

The six study areas were located along the western shore of Long Island Sound in southwestern Connecticut (Figure 1): 1) Cos Cob Harbor (Greenwich; 126-acre intertidal area), 2) Grays Creek (Westport; 35-acre intertidal zone), 3) Scott Cove (Darien; 121-acre intertidal area), 4) Five Mile River (Darien/Norwalk; 18-acre intertidal zone), 5) Greenwich Cove (100-acre intertidal area), and 6) Canfield Island Cove (Norwalk; 109-acre intertidal area). The spring tide range in this area is about 8.0 feet (i.e., 8.3 feet in Cos Cob Harbor; http://co-ops.nos.noaa.gov/tide_pred.html), which is more than twice the range as in Long Island Sound estuaries east of the Connecticut River. The mean tide range is approximately 7.0 feet (i.e., 7.2 feet for Cos Cob Harbor).

Figure 1. General location of study estuaries along the Connecticut coast (see Appendix A for detailed maps).



## METHODS

Digital images of aerial photography for the study areas were provided by the LIS Program for the following years: 1974, 1981, 1986, 1990, 1995, 2000, and 2004. These images were georeferenced in Connecticut State Plane Coordinates (NAD 83). The boundaries of salt marsh complexes for each of the sites were delineated and saved as a shapefile in Connecticut State Plane Coordinates (NAD 83) for each of the study sites and for each year of photography.

For each study site, aerial photographs were interpreted on-screen and the following features were delineated for each era: low marsh, high marsh, and tidal flat. The area of each feature was then calculated for each study area and for each time period. In most cases, the aerial photographs were captured at low tide, so the limits of tidal flats could be detected. In eras where the aerial photos were not low-tide synchronized, the tidal flats from the other time periods were assumed to be present. Where human-induced changes were detected, the extent and nature of the change was recorded.

A geospatial data base was created to store data on wetland changes. This data base was used to generate maps and statistics of salt marsh trends. Statistics were generated to reflect the area of low marsh, area of high marsh, area of tidal flat (depending on stage of tide), the overall area of tidal wetland for each time period, and the extent of human-induced changes. These data were then used to demonstrate wetland changes between years (at approximately five-year intervals). A series of maps showing the changes for each salt marsh complex was generated. A metadata file for this project was also created to document source data and other pertinent information about the project and interpretations.

## RESULTS

All study areas experienced a decline in low marsh from 1974 to 2004 and a gain in tidal flats, while all areas, except Cos Cob Harbor, also experienced a loss in high marsh (Table 1). Figures 2 through 7 show the changes in low marsh, high marsh, and tidal flat at various intervals over the past 30 years.

Canfield Island Cove was unique in that it had a small gain in open water (0.22 acres) and a gain in palustrine tidal wetland (0.31 acres). Over the 30-year study period, it experienced a 26% gain in tidal flat, while losing 27% of its low marsh and about 4% of its high marsh. Aquatic beds appeared to decline by nearly 40%. Aerial photos for 1974 and 2000 are provided in Appendix B to illustrate the changes in these wetlands.

Cos Cob Harbor was the only study estuary to show a gain in high marsh from 1974-2004, with a negligible 0.4-acre gain (2.5% increase). Tidal flat acreage increased by about 5 acres (30% gain), largely at the expense of low marsh which declined by 30%.

Five Mile River gained nearly 4 acres (67%) of tidal flat that formed in areas of former marsh. Nearly half of the low marsh was converted to tidal flat as was nearly one-fifth of its high marsh.

Similarly, Grays Creek estuary lost low marsh and high marsh to tidal flat which increased in acreage by 37%. Over half of the low marsh and about one-third of the high marsh acreage declined over the 30-year study period. Aerial photos for 1974 and 2000 are provided in Appendix B to illustrate the changes in these wetlands.

Greenwich Cove lost nearly 50% of its low marsh and only 8% of its high marsh from 1974-2004. These losses were countered by a nearly 11-acre gain (19%) in tidal flat.

Scott Cove, like the other areas in this study, experienced a gain in tidal flat at the expense of salt marsh. The nearly 17-acre gain in the former was the result of losses of 16 acres of low marsh and about 1 acre of high marsh. This was the largest acreage loss of low marsh among the six study areas.

Table 1. Acreage changes in study salt marshes from 1974 to 2004.

| Salt Marsh System | Marsh Zone | 1974 | 1981 | 1986 | Acreage 1990 | 1995 | 2000 | 2004 | Overall Acreage Change (% Change) |
|---|---|---|---|---|---|---|---|---|---|
| Canfield Island Cove | Tidal Flat | 32.15 | 32.72 | 34.58 | 37.58 | 38.16 | 39.87 | 40.51 | +8.36 (26.0) |
| | Low Marsh | 27.61 | 27.08 | 25.36 | 22.53 | 21.90 | 20.62 | 20.06 | -7.55 (27.3) |
| | High Marsh | 48.13 | 47.71 | 47.25 | 47.07 | 46.71 | 46.36 | 46.42 | -1.71 (3.5) |
| | Open Water | 14.95 | 14.95 | 14.95 | 14.87 | 14.89 | 14.95 | 15.17 | +0.22 (1.5) |
| | Aquatic Bed | 0.80 | 0.75 | 0.78 | 0.78 | 0.78 | 0.81 | 0.49 | -0.31 (38.8) |
| | Beaches | 0.50 | 0.41 | 0.45 | 0.43 | 0.47 | 0.47 | 0.47 | -0.03 (6.0) |
| | Palustrine Tidal | 0.00 | 0.00 | 0.45 | 0.53 | 0.84 | 0.31 | 0.31 | +0.31 (na) |
| Cos Cob Harbor | Tidal Flat | 17.41 | 19.33 | 21.68 | 22.40 | 22.27 | 22.70 | 22.67 | +5.26 (30.2) |
| | Beach | 73.57 | 73.57 | 73.57 | 73.57 | 73.57 | 73.57 | 73.57 | 0.00 (0.0) |
| | Rocky Shore | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.00 (0.0) |
| | Low Marsh | 19.38 | 17.09 | 14.77 | 13.88 | 13.90 | 13.56 | 13.58 | -5.80 (29.9) |
| | High Marsh | 15.85 | 16.15 | 15.94 | 16.19 | 16.30 | 16.25 | 16.25 | +0.40 (2.5) |
| | Aquatic Bed | 16.55 | 16.61 | 16.69 | 16.61 | 16.61 | 16.58 | 16.58 | +0.03 (0.0) |
| Five Mile River | Tidal Flat | 5.78 | 6.79 | 7.22 | 8.59 | 9.54 | 9.63 | 9.63 | +3.85 (66.6) |
| | Low Marsh | 5.75 | 5.38 | 5.33 | 4.23 | 2.97 | 2.93 | 3.04 | -2.71 (47.1) |
| | High Marsh | 6.56 | 5.92 | 5.53 | 5.27 | 5.53 | 5.48 | 5.37 | -1.19 (18.1) |
| Grays Creek | Tidal Flat | 18.36 | 20.15 | 21.48 | 23.31 | 24.17 | 24.95 | 25.21 | +6.85 (37.3) |
| | Beach | 0.41 | 0.37 | 0.31 | 0.32 | 0.35 | 0.35 | 0.32 | -0.09 (22.0) |
| | Low Marsh | 7.57 | 5.99 | 6.05 | 4.94 | 4.09 | 3.66 | 3.52 | -4.05 (53.5) |
| | High Marsh | 8.22 | 8.06 | 6.73 | 5.99 | 5.89 | 5.52 | 5.52 | -2.70 (32.8) |
| | Aquatic Bed | 0.07 | 0.07 | 0.07 | 0.07 | 0.13 | 0.15 | 0.07 | 0.00 (0.0) |
| | Open Water | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.00 (0.0) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Greenwich Cove | Tidal Flat | 56.39 | 58.95 | 62.84 | 64.35 | 66.11 | 67.50 | 67.12 | +10.73 (19.0) |
| | Beach | 2.92 | 2.90 | 3.10 | 2.84 | 2.98 | 2.42 | 2.91 | -0.01 (0.0) |
| | Low Marsh | 19.62 | 17.09 | 13.48 | 12.35 | 11.04 | 10.50 | 10.40 | -9.22 (47.0) |
| | High Marsh | 21.30 | 21.01 | 20.52 | 20.40 | 19.81 | 19.52 | 19.52 | -1.78 (8.4) |
| | Open Water | 14.79 | 14.79 | 14.79 | 14.79 | 14.79 | 14.79 | 14.79 | 0.00 (0.0) |
| | Aquatic Bed | 3.41 | 3.41 | 3.41 | 3.41 | 3.41 | 3.41 | 3.41 | 0.00 (0.0) |
| Scott Cove | Tidal Flat | 71.67 | 83.48 | 83.93 | 88.65 | 88.23 | 88.46 | 88.46 | +16.79 (23.4) |
| | Low Marsh | 33.39 | 21.87 | 21.76 | 17.01 | 17.44 | 17.22 | 17.22 | -16.17 (48.4) |
| | High Marsh | 16.39 | 16.09 | 15.75 | 15.79 | 15.72 | 15.72 | 15.72 | -0.67 (4.1) |
| | Open Water | 3.03 | 3.03 | 3.03 | 3.03 | 3.03 | 3.03 | 3.03 | 0.00 (0.0) |

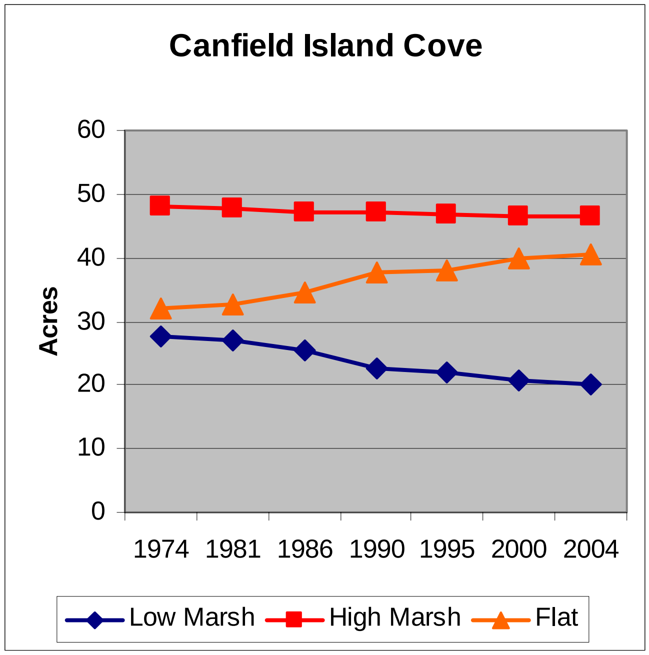



Figure 2. Trends for Canfield Island Cove.

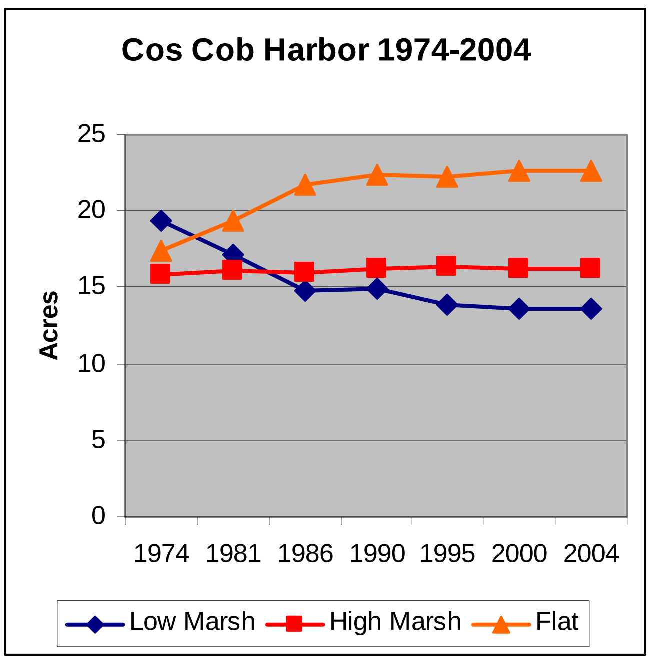



Figure 3. Trends for Cos Cob Harbor.

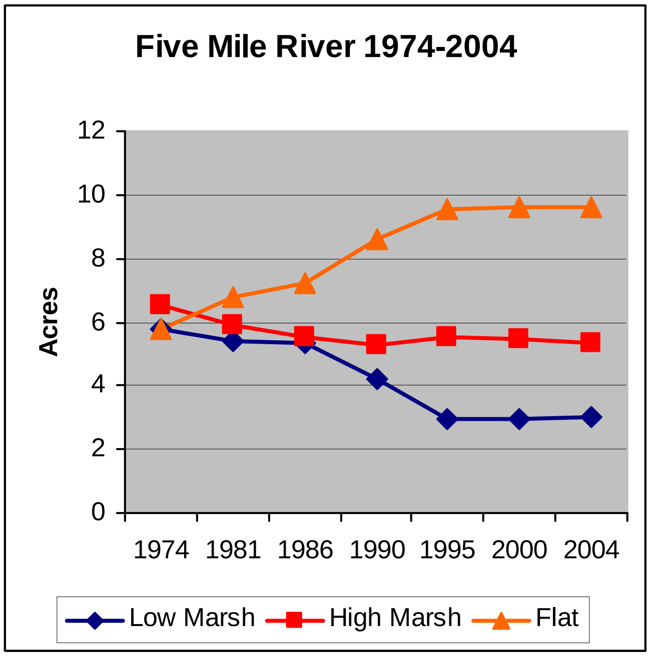



Figure 4. Trends for Five Mile River.

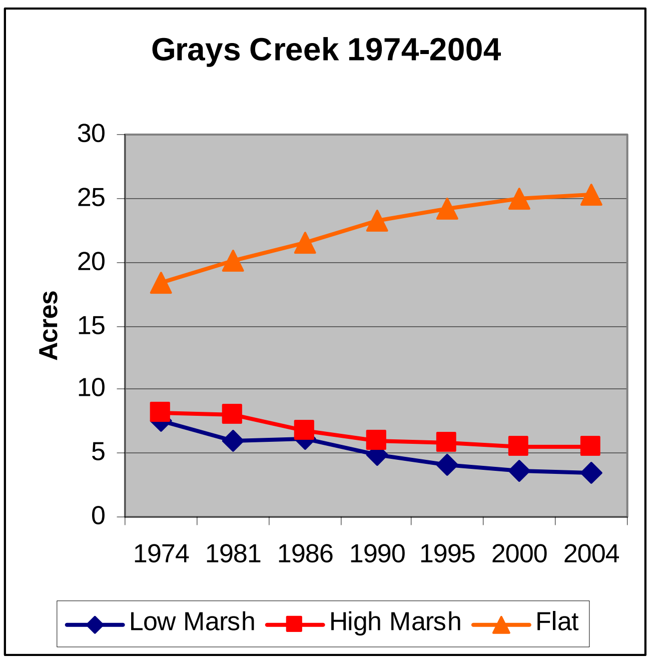



Figure 5. Trends for Grays Creek.

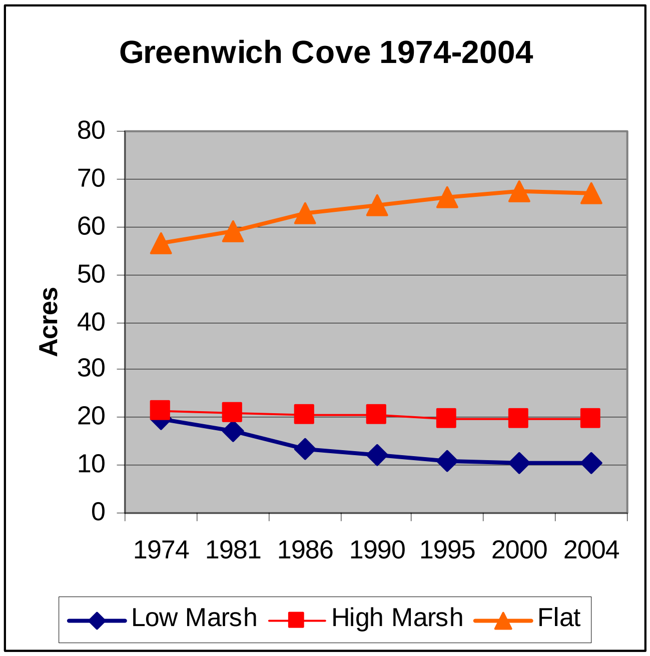



Figure 6. Trends for Greenwich Cove.

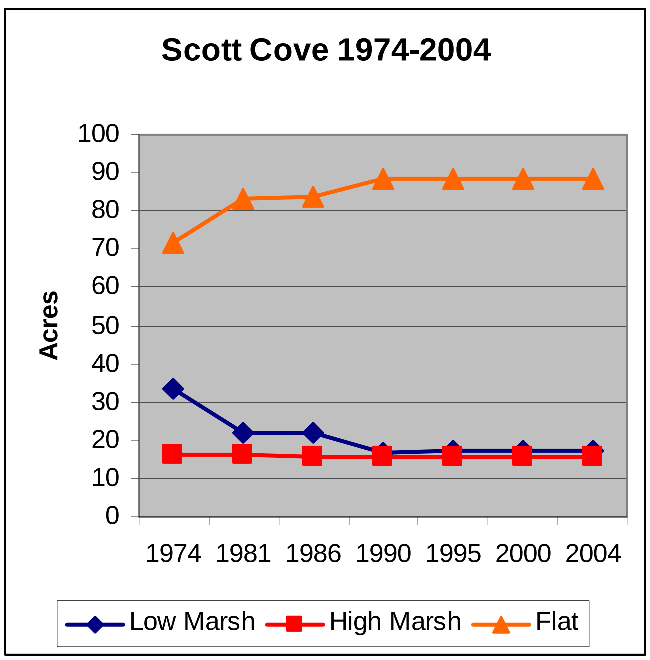
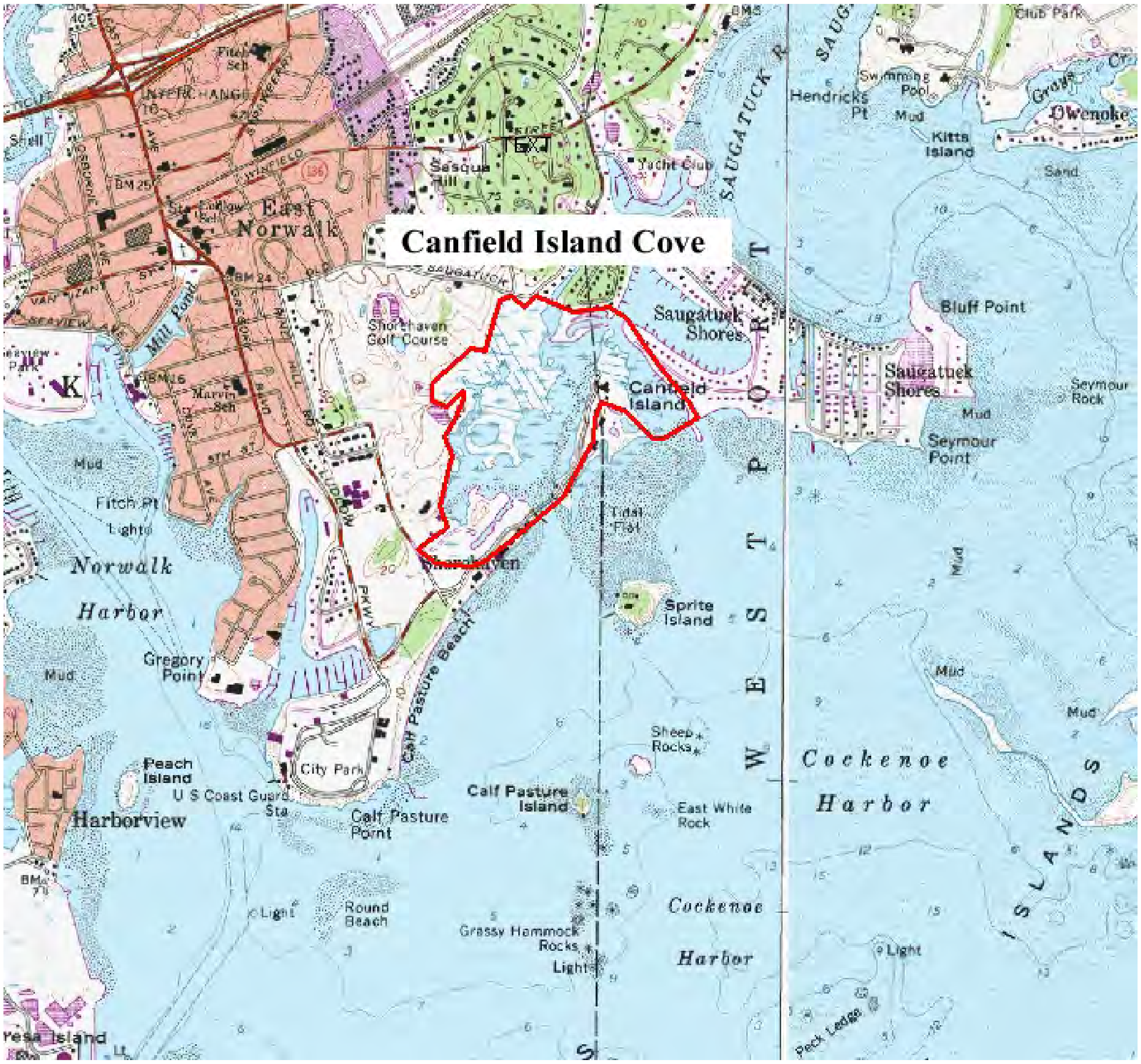
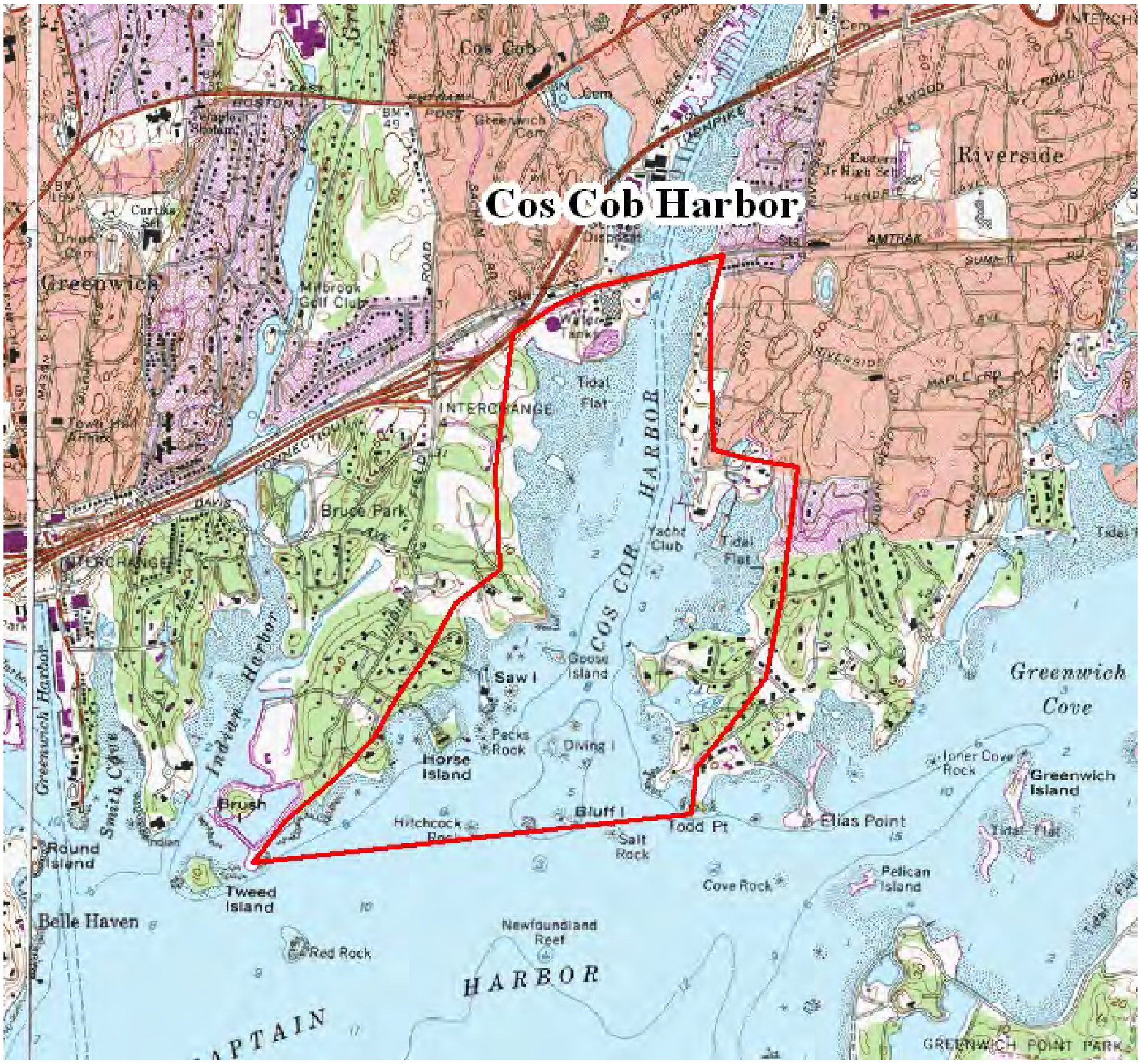



Figure 7. Trends for Scott Cove.

## APPENDICES.

**Appendix A.  Maps showing location of study areas.**


Canfield Island Cove
East Norwalk
Sasqua Hill
Yacht Club
Saugatuck Shores
Canfield Island
Shorehaven Golf Course
Hendricks Pt
Kitts Island
Bluff Point
Seymour Point
Seymour Rock
Mill Pond
Fitch Pt
Norwalk Harbor
Gregory Point
Tidal Flat
Sprite Island
Sheep Rocks
Calf Pasture Beach
City Park
Peach Island
U S Coast Guard Sta
Calf Pasture Point
Calf Pasture Island
East White Rock
Harborview
Round Beach
Grassy Hammock Rocks
Light
Cockenoe Harbor
Peck Ledge
WESTPORT
Owenoke
Saugatuck R
Mud
Sand


Cos Cob Harbor
Riverside
Greenwich
Bruce Park
COS COB HARBOR
Greenwich Cove
Horse Island
Saw I
Bluff I
Todd Pt
Elias Point
Tweed Island
Round Island
Belle Haven
Red Rock
Newfoundland Reef
HARBOR
Greenwich Island
Pelican Island
Cove Rock
Salt Rock
GREENWICH POINT PARK


Five Mile River
Rowayton Sta
Rowayton
Wilson Cove
Wilson Pt
Hoyt Island
Tidal Flat
Cedar Hammock
Little Tavern Island
Tavern Island
Yellow Rock
Bell Island
Sheffield Island
Harbor
Dog Isla
Butlers Island
Roton Pt
Pine Pt
Noroton Point
Ballast Reef
Contentment Island
Fish Islands
Sheffield Island
Greens Ledge
Old Baldy
Hiding Rocks
Great Reef
Fivemile River
Farm Cr


Grays Creek
Saugatuck
Westport Sta
SAUGATUCK RIVER
Hendricks Pt
Stony Pt
Club Park
Swimming Pool
Owenoke
Kitts Island
Compo
Compo Hill
Hale Court
Compo Cove
Compo Beach
Yacht Basin
Cedar Point
Bluff Point
Saugatuck Shores
Canfield Island
Seymour Rock
Seymour Point
Sprite Island
Sherwood Millpond
Mill Cr
SHERWOOD STATE
WESTPORT
CONNECTICUT TPKE
PENN CENTRAL
Sand
Mud
Gravel


Greenwich Cove
Riverside
Old Greenwich
Greenwich Cove
COS COB HARBOR
Greenwich Island
Elias Point
Todd Pt
Pelican Island
Inner Cove Rock
Cove Rock
Tidal Flat
GREENWICH POINT PARK
Greenwich Point
Flat Neck Point
Goose Island
Saw I
Pecks Rock
Diving I
Bluff I
Salt Rock
Newfoundland Reef
HARBOR
Yacht Club
Golf Course
Tomac Cem
AMTRAK


Scott Cove
Tokeneke
Noroton
Gorhams Pond
Tidal Flat
Scott Cove
Great Island
Hay I
Fish Islands
Contentment Island
Butlers Island
Ballast Reef
Roton Pt
Pine Pt
Rowayton
Greens Ledge Lighthouse
Nash Island
Spring Grove Cemetery
Mather Jr HS
INTERCHANGE
Sacred Heart

**Appendix B. Aerial photos for Canfield Island Cove and Grays Creek (1974 vs. 2000)**.

CANFIELD ISLAND COVE – YR 1974 (ABOVE), YR 2000 (BELOW)

GRAYS CREEK - YR 1974 (ABOVE), YR 2000 (BELOW)