Should (R)SET-MH data be used to forecast the effects of sea level rise on wetland resilience and carbon sequestration?

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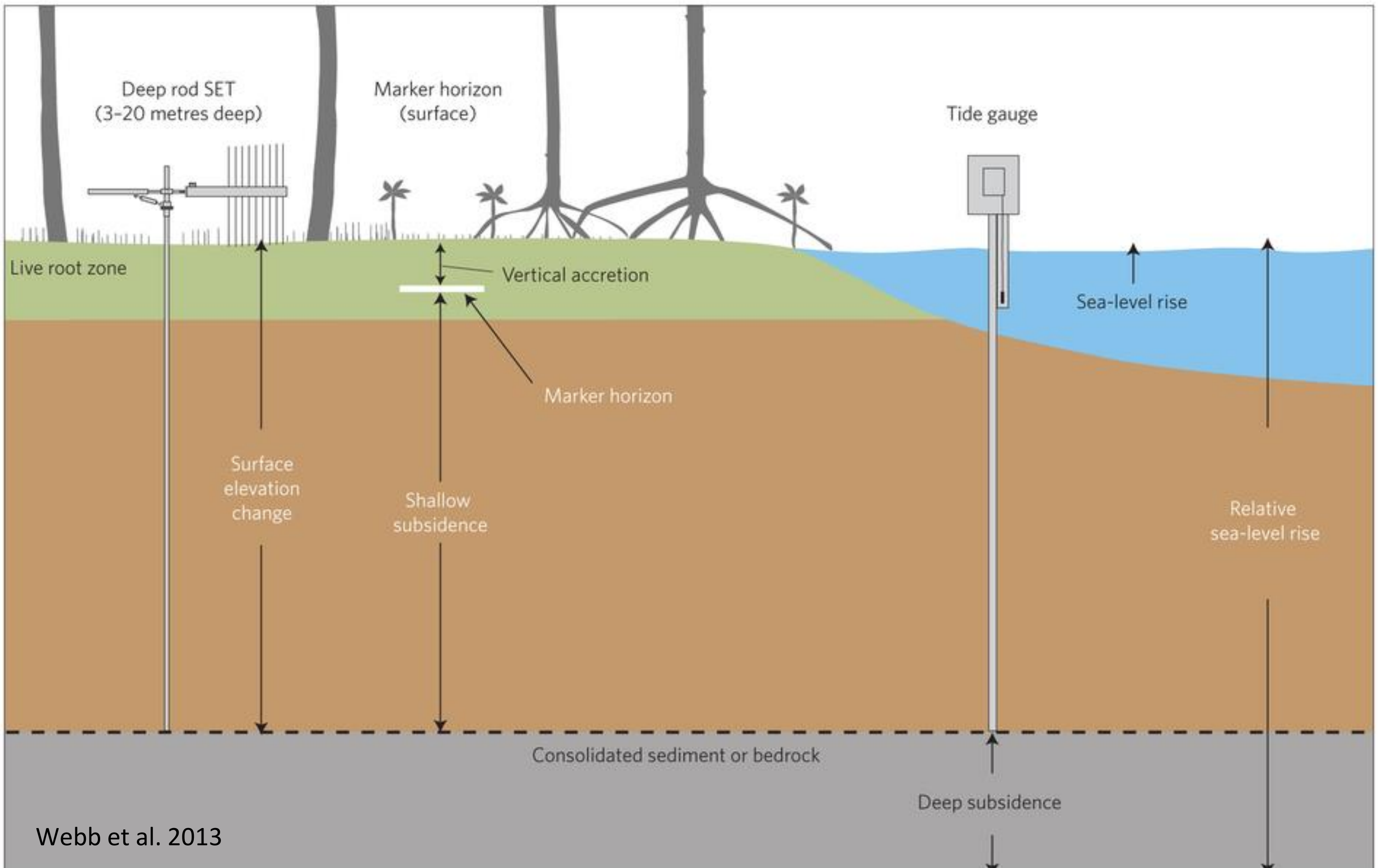


ABSTRACT

PARKINSON, R.W.; DELAUNE, R.D., and WHITE, J.R., 1994. Holocene sea-level rise and the fate of mangrove forests within the Wider Caribbean Region. *Journal of Coastal Research,* 10(4), 1077–1086. Fort Lauderdale (Florida), ISSN 0749-0208.

This paper (1) reviews mangrove forest peat accretion data obtained from carbonate settings of the Wider Caribbean Region and (2) evaluates the fate of these forests based upon current global eustatic sea-level rise projections. Historical peat accretion rates calculated using ^{137}Cs or ^{210}Pb average 3.7 mm yr^{-1}. Peat accretion rates calculated using ^{14}C average 1.0 mm yr^{-1}. The discrepancy between historical and geological accretion rates, also recognized in salt marsh settings, is attributed to organic decomposition and sediment compaction.

Our conceptual model, which is based upon comparisons between projected rates of global eustatic sea-level rise and peat accretion, predicts stable forest conditions only if historical accretion rates persist during a conservative (low) sea-level rise of ~1.3 mm yr^{-1}. Best guess (middle) and high estimates of a sea-level rise of as much as 8 mm yr^{-1} will likely submerge mangrove forests located within carbonate settings of the Wider Caribbean Region.

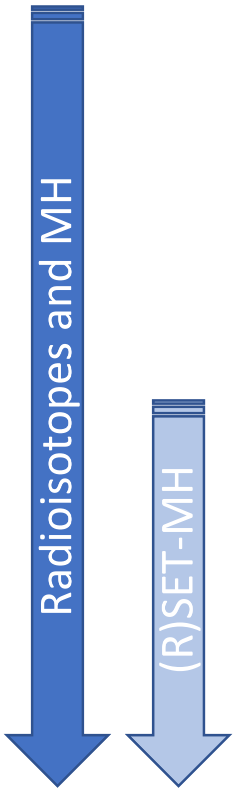
What has changed since then:

- Introduction of (R)SET-MH methodology to quantify recent sedimentation
- Increased rate and magnitude of sea level rise forecast to accompany climate change

What has not changed:

- Sedimentation rate discrepancies between methodologies, including (R)SET-MH, have not been resolved

So what?



Pilot studies and formulation of standard methods	Objective	Why
1970s and 80s	Above and below ground processes including biogeochemistry and sedimentation	How wetlands work
1980s and early-90s	Historic change in sedimentation	Resiliency of habitat and ecosystem function to sea level rise and civil engineering
Mid-1990s and 00s	Recent sedimentation	Resiliency (SLAMM) and restoration success (BACI)
2000s and 10s	Carbon flux	Climate change

Evolution of approach and rationale used in wetland studies designed to quantify temporal and spatial changes in sedimentation

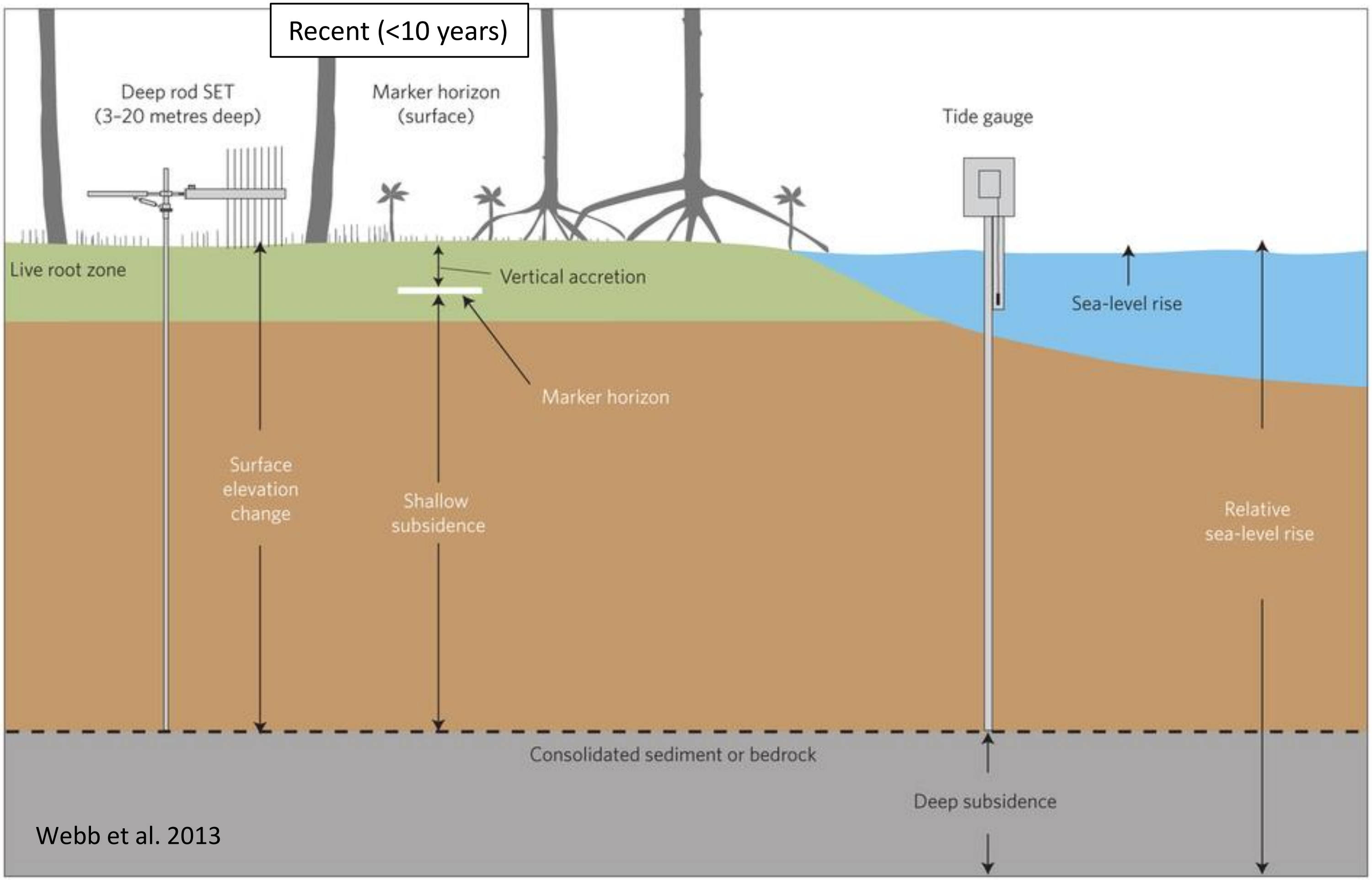
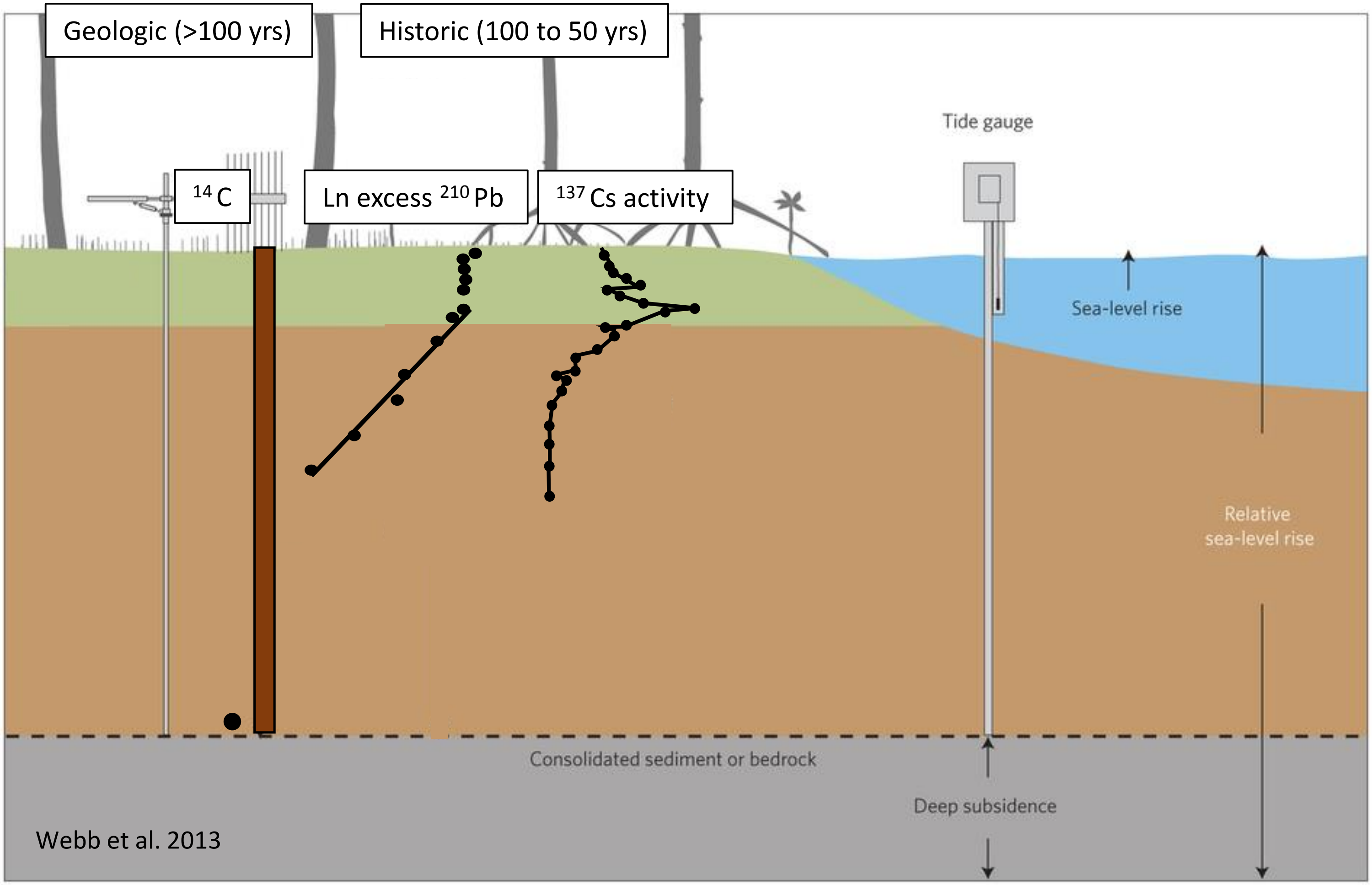


Figure 1. RSET-MH set-up in a coastal mangrove to quantify recent sedimentation. From Webb et al. 2013.



Radioisotope geochronology data used to quantify geologic and historic sedimentation. Modified after Webb et al. 2013.

Location	(R)SET-MH			Radiometric			Reference
	Recent			Historic		Geologic	
	Duration of observations (mo)	Accretion	Elevation change	Cs-137	Pb-210	C-14	
Wetlands (207)							
Maine	204	2.84 (11)					Goodman et al. 2007
Massachusetts						1.83 (2)	Redfield 1972
New York					0.02		Kolker et al. 2010
New York				2.30	2.10		Donnelly and Bertness 2001
Chesapeake Bay	60	20.48 (8)	17.64 (9)				Cadol et al. 2014
Chesapeake Bay					2.35	0.82	Hussein 2009
South Carolina	60	7.73 (4)	3.08 (4)				Stagg et al. 2016
Georgia	60	14.73 (4)	11.2 (4)				Stagg et al. 2016
Georgia	7	6.40 (3)		1.93 (3)			Craft 2007
Georgia				3.70			Loomis and Craft 2010
Florida				1.60	0.50	0.48 (4)	Craft and Richardson 2008
Florida						0.10 (6)	Choi and Wang 2004
Louisiana				2.48 (6)			Nyman et al. 2006
Louisiana				8.58	5.85		Jarvis 2010
Louisiana	60	13.70 (2)	2.9 (2)	6.85 (2)	5.75 (2)		Rybczyk and Cahoon 2002
Louisiana		10.02 (9)	-3.17 (9)				Lane et al. 2006
Louisiana				4.97 (6)	2.95 (6)		Prouhet 2001
Louisiana	48	16.40	3.50				Baustain et al. 2012
Louisiana				10.50 (2)			DeLaune 1978
Louisiana				1.43		1.18 (4)	DeLaune et al. in review
Louisiana				7.69 (6)	4.29 (3)	3.55 (15)	Smith 2009
Louisiana				5.26 (9)	4.49 (9)		Smith 2012
Texas					3.94 (32)		White et al. 2002
Western Gulf of Mexico				3.90 (2)	3.10 (2)		Turner et al. 2006
Gulf of Mexico				3.62 (4)			Callaway et al. 1997
Average		11.54	5.99	4.71	3.21	1.36	

Estimates of Atlantic and Gulf Coast marsh accretion rates (mm/yr) organized by location and method. Values decrease with increasing age of sediment (left to right). (11) = number of observations if more than one.

Location	(R)SET-MH			Radiometric			Reference
	Recent			Historic		Geologic	
	Duration of observations (mo)	Accretion	Elevation change	Cs-137	Pb-210	C-14	
Mangrove (65)							
Hutchinson Island, Florida				9.50 (5)		1.00 (6)	Parkinson et al. 1994
Florida Keys				3.22 (5)			Callaway et al. 1997
Southwest Florida	36	9.00 (2)	3.80 (2)				Whelan et al. 2009
Southwest Florida					3.05 (2)		Smoak et al. 2013
Southwest Florida						0.60 (3)	Parkinson et al. 1994
Southwest Florida						1.10 (2)	Parkinson et al. 1994
Rookery Bay, Florida	30	6.34 (5)	2.34 (5)				Cahoon and Lynch 1997
Rookery Bay, Florida	36	3.66 (7)	2.11 (7)				McKee 2011
Rookery Bay, Florida				1.80	1.60		Lynch et al. 1989
Naples Bay, Florida				4.16 (5)	2.52 (7)		Marchia et al. 2016
Average		6.33	2.75	4.67	2.39	0.90	

Estimates of Atlantic and Gulf Coast mangrove accretion rates (mm/yr) organized by location and method. Values decrease with increasing age of sediment (left to right). (11) = number of observations if more than one.

PERSPECTIVE
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nature climate change

A global standard for monitoring coastal wetland vulnerability to accelerated sea-level rise

Edward L. Webb[1]*, Daniel A. Friess[2,3]*, Ken W. Krauss[4], Donald R. Cahoon[5], Glenn R. Guntenspergen[5] and Jacob Phelps[1]

Sea-level rise threatens coastal salt-marshes and mangrove forests around the world, and a key determinant of coastal wetland vulnerability is whether its surface elevation can keep pace with rising sea level. Globally, a large data gap exists because wetland surface and shallow subsurface processes remain unaccounted for by traditional vulnerability assessments using tide gauges. Moreover, those processes vary substantially across wetlands, so modelling platforms require relevant local data. The low-cost, simple, high-precision rod surface-elevation table–marker horizon (RSET-MH) method fills this critical data gap, can be paired with spatial data sets and modelling and is financially and technically accessible to every country with coastal wetlands. Yet, RSET deployment has been limited to a few regions and purposes. A coordinated expansion of monitoring efforts, including development of regional networks that could support data sharing and collaboration, is crucial to adequately inform coastal climate change adaptation policy at several scales.

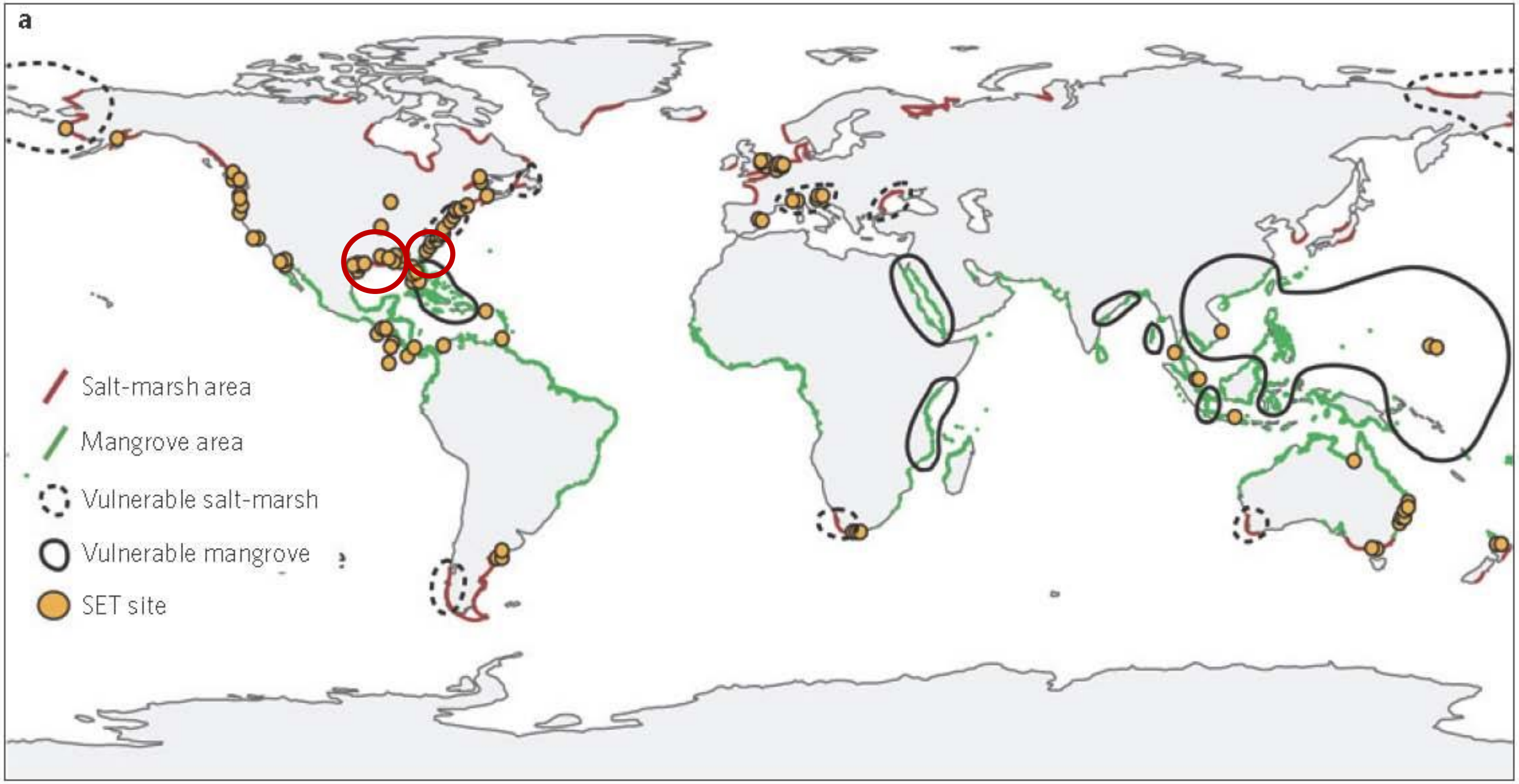


Figure 3a. Published global distribution of coastal wetlands. Those hypothesized to be vulnerable to increases in relative sea-level encircled. Known SET locations plotted as orange circles. From Webb et al. 2013.

nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 24 FEBRUARY 2016 | DOI: 10.1038/NCLIMATE2909

Overestimation of marsh vulnerability to sea level rise

Matthew L. Kirwan[1]*, Stijn Temmerman[2], Emily E. Skeehan[1], Glenn R. Guntenspergen[3] and Sergio Fagherazzi[4]

Coastal marshes are considered to be among the most valuable and vulnerable ecosystems on Earth, where the imminent loss of ecosystem services is a feared consequence of sea level rise. However, we show with a meta-analysis that global measurements of marsh elevation change indicate that marshes are generally building at rates similar to or exceeding historical sea level rise, and that process-based models predict survival under a wide range of future sea level scenarios. We argue that marsh vulnerability tends to be overstated because assessment methods often fail to consider biophysical feedback processes known to accelerate soil building with sea level rise, and the potential for marshes to migrate inland.

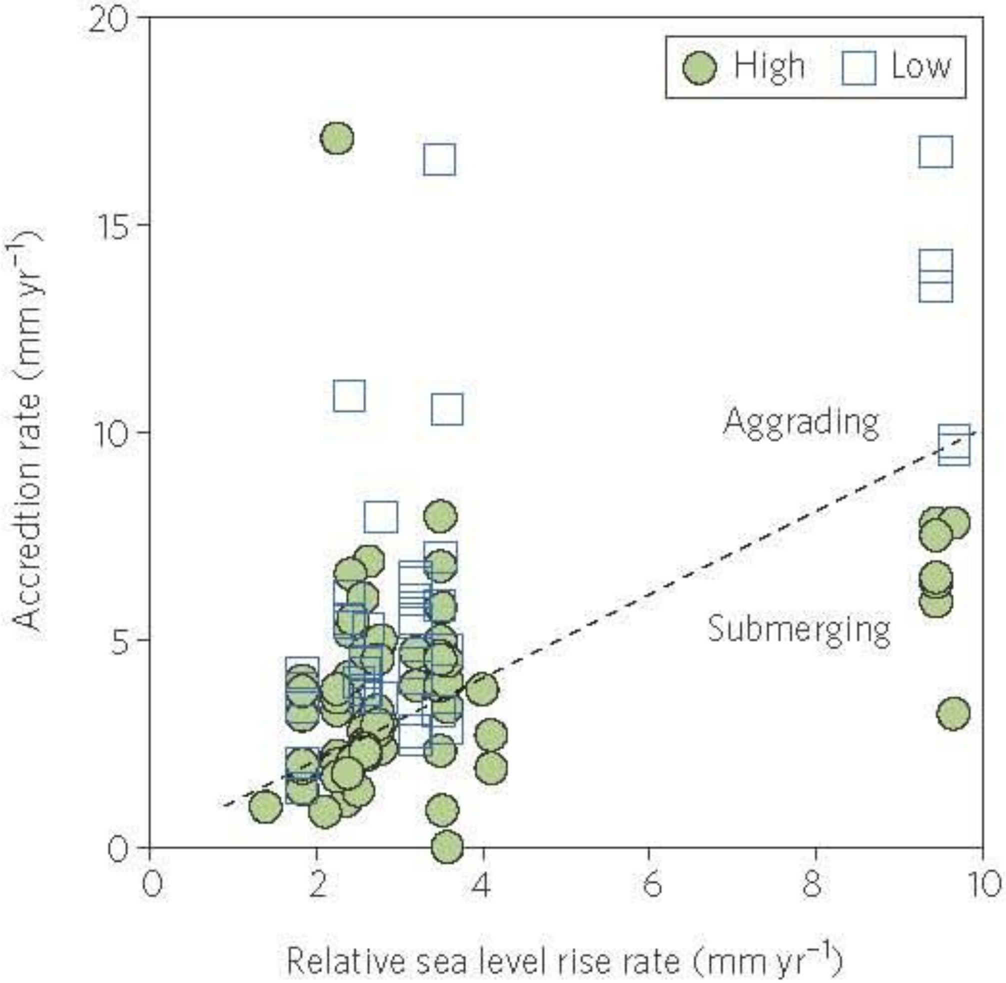


Figure 1a. Comparison between local relative sea level rise and accretion rates for low- and high-elevation marshes of Atlantic and Gulf Coast salt marshes in North America and Europe. Dashed line is 1:1. From Kirwan et al. 2016.

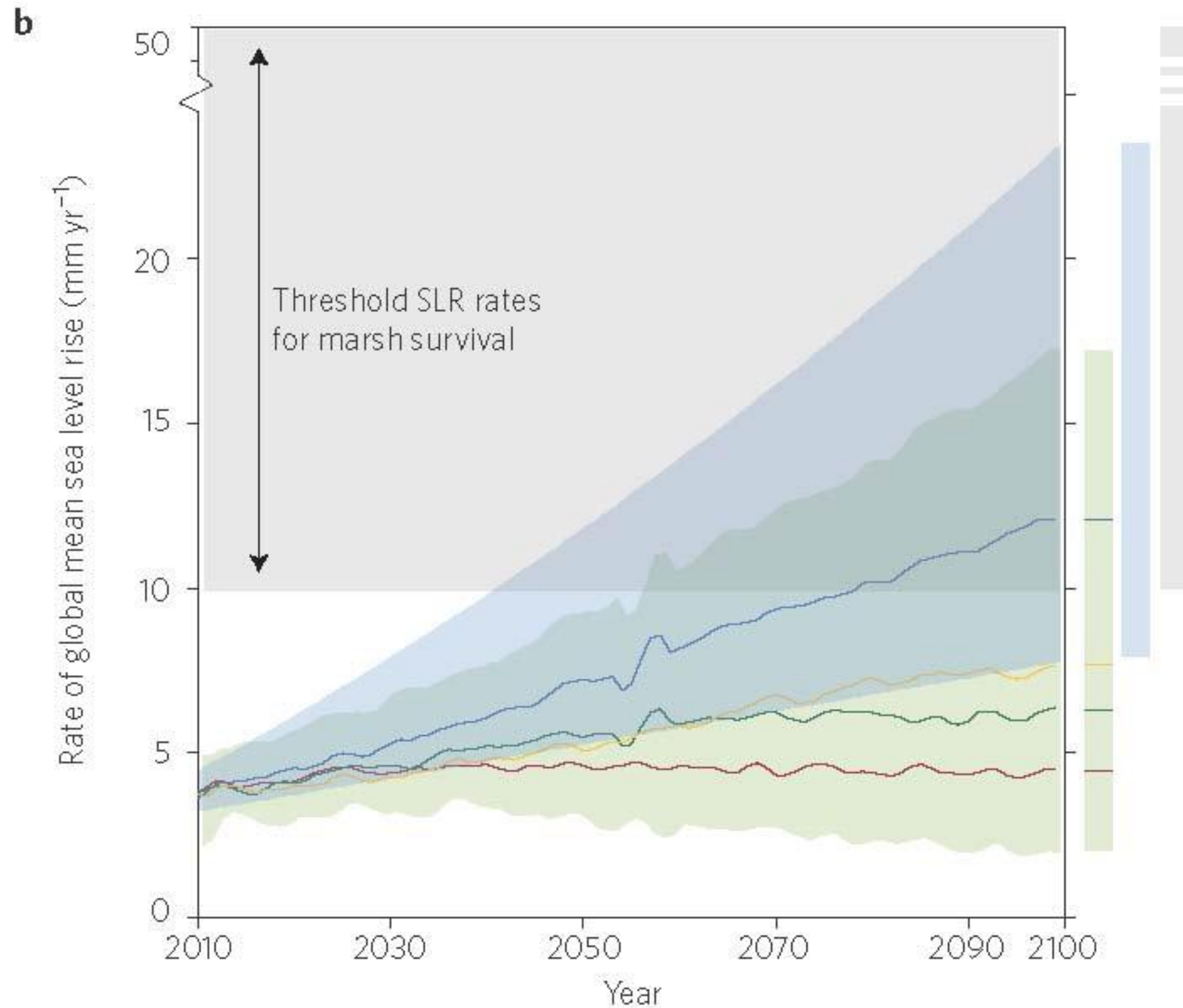
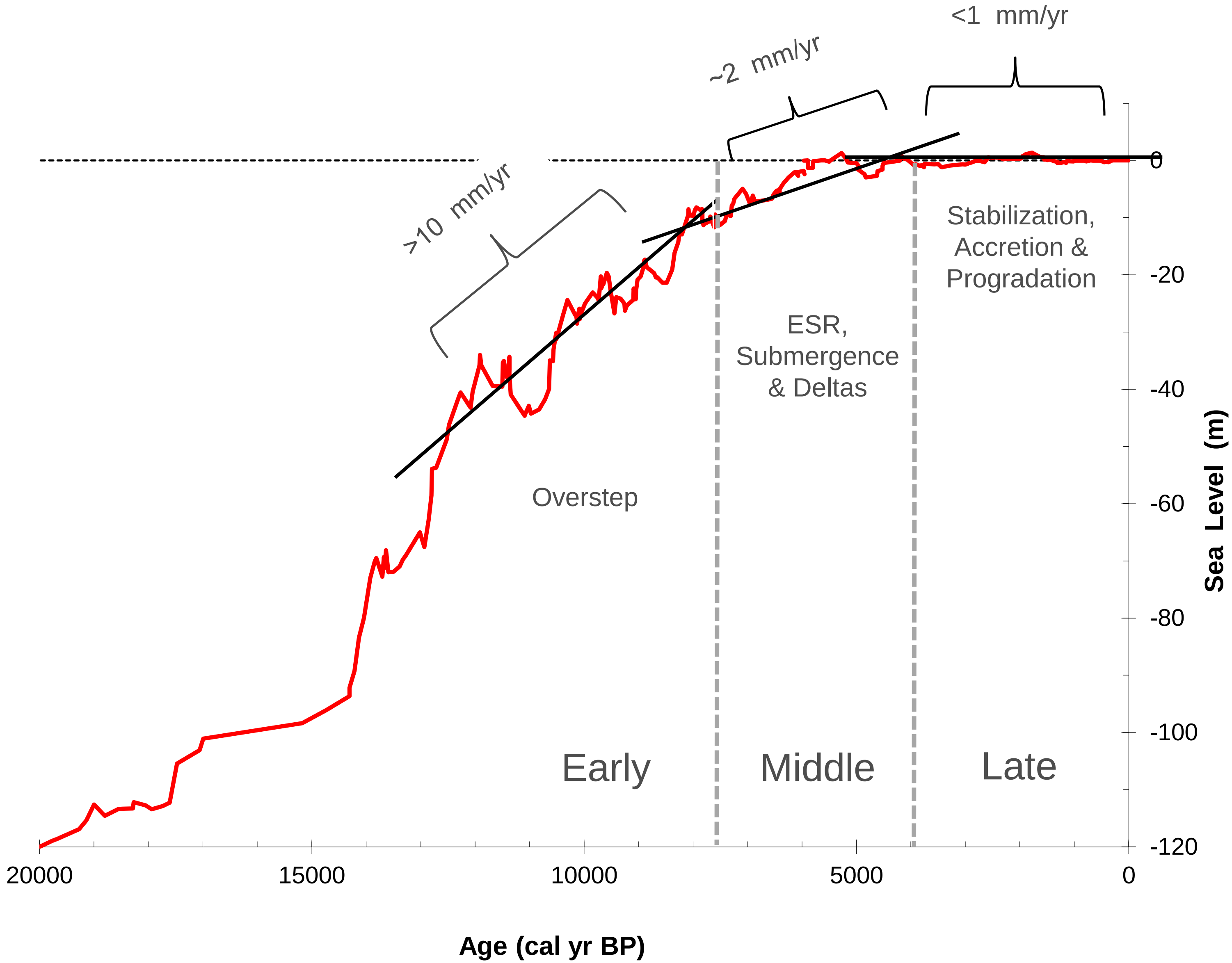


Figure 3b. Threshold rates of sea level rise (grey band) above which marshes are not able to survive. The predicted probable range of global sea level rise rates in 2100 is indicated by the pale green and blue bands (IPCC AR5). From Kirwan et al. 2016.



Coastal response to sea level rise during Holocene Epoch (southeastern USA). ERS = erosional shoreface retreat. Sea level history from Balsillie and Donoghue (2004).

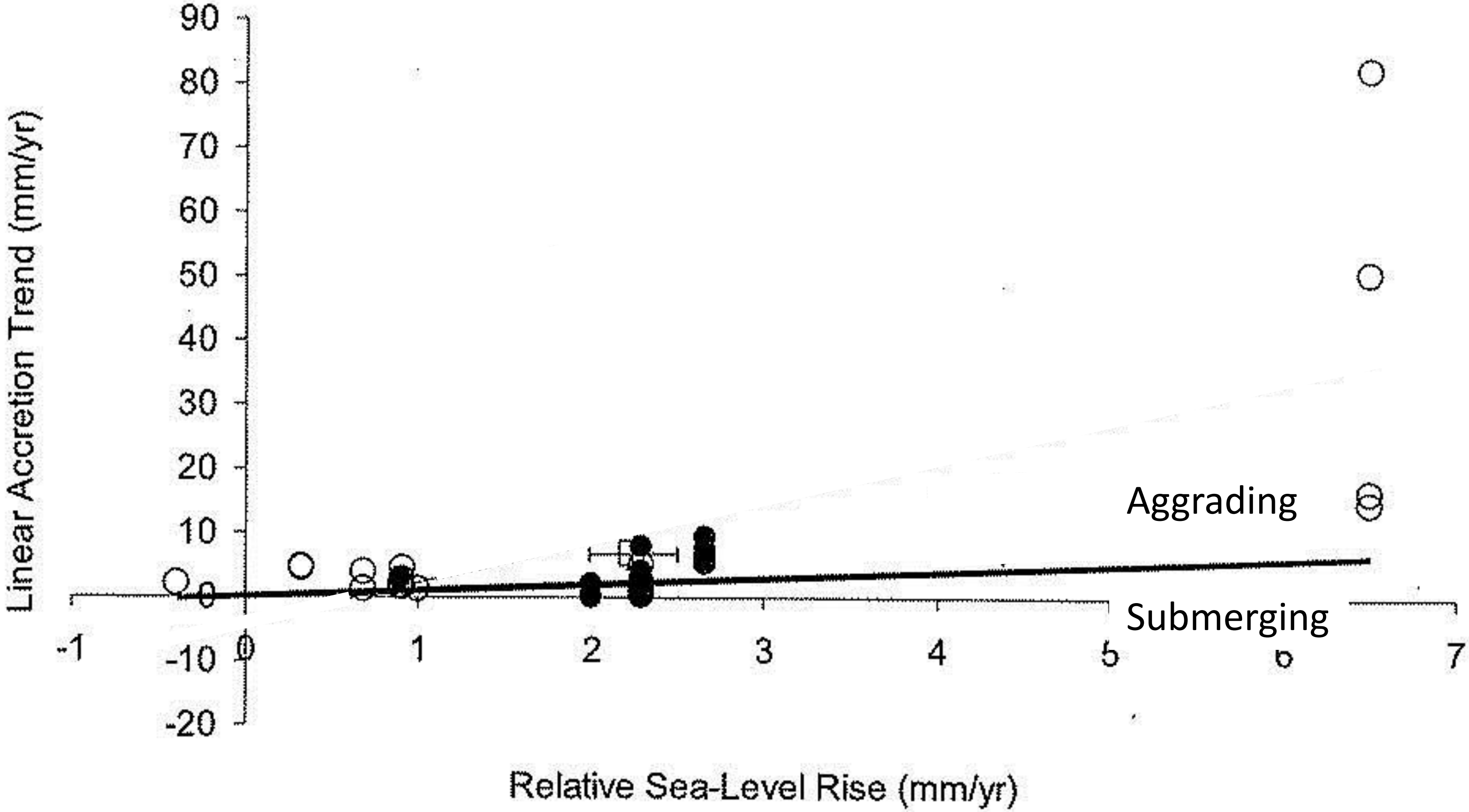


Figure 12.8. Linear trend in accretion verses relative sea level rise for mangrove sites in the SET network. From Cahoon et al. 2006.

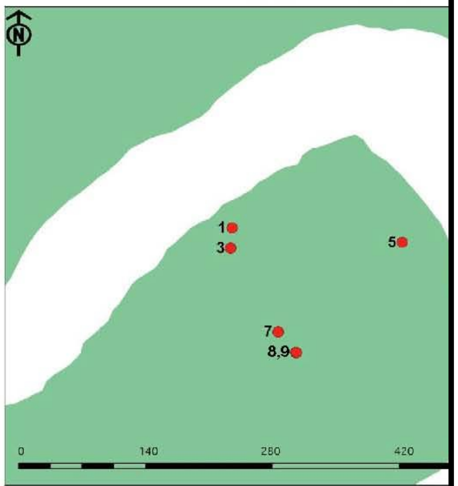
(R)SET-MH Summary of Observations

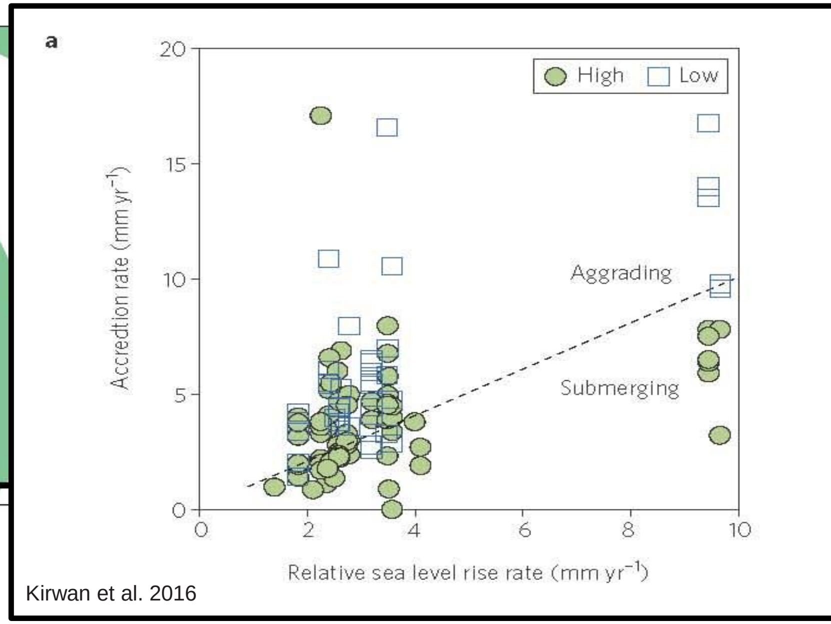
- SET-MH rates of coastal marsh sedimentation yield higher values than those based upon radiometric geochronology.

- SET-MH data generally represent less than a decade of observations. So the cumulative effects of subsurface processes have likely not been fully integrated into the stratigraphic sequence.

- Predictive models using SET-MH data forecast marsh resilience at rates of SLR inconsistent with the Holocene stratigraphic record.

- Radiometric geochronology is a more viable means of forecasting resilience because it yields estimates of marsh sedimentation operating over decades to centuries – the same interval over which predictions of climate change and SLR are typically discussed.





ure 1. Location of six (6)
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rk River Basin of
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m Breithaupt et al. 2014

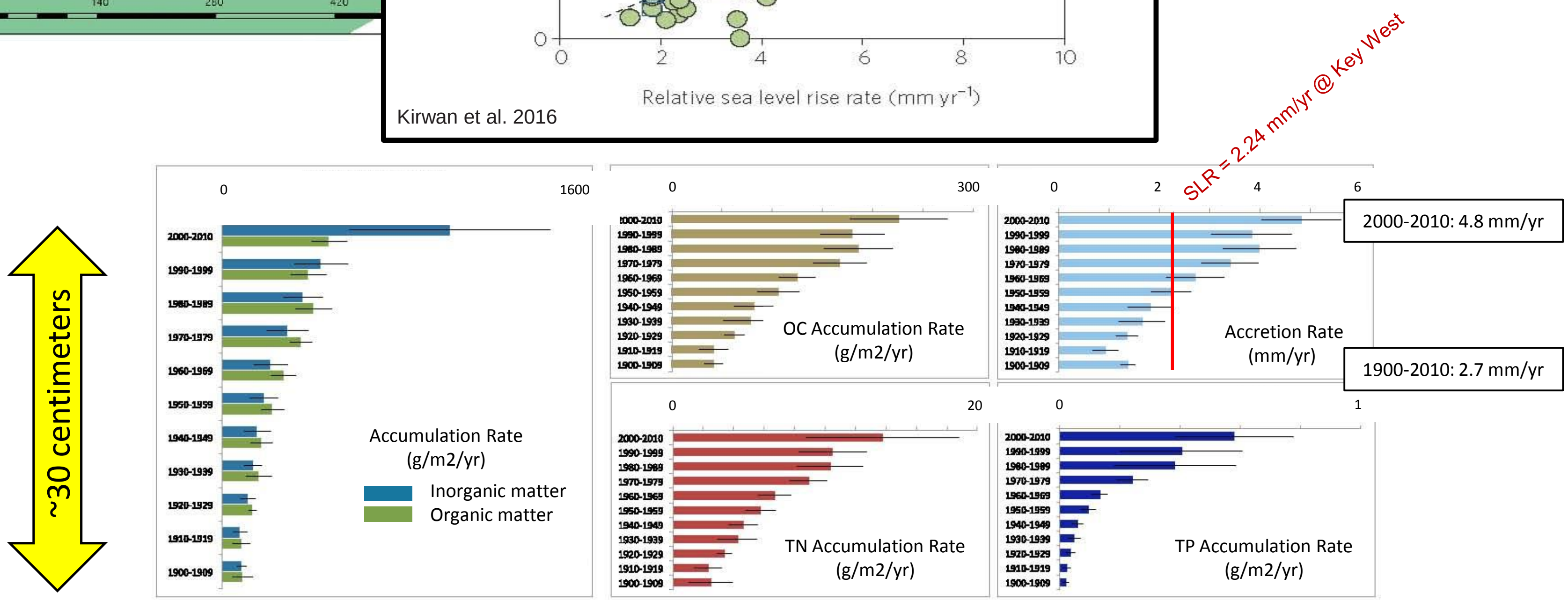
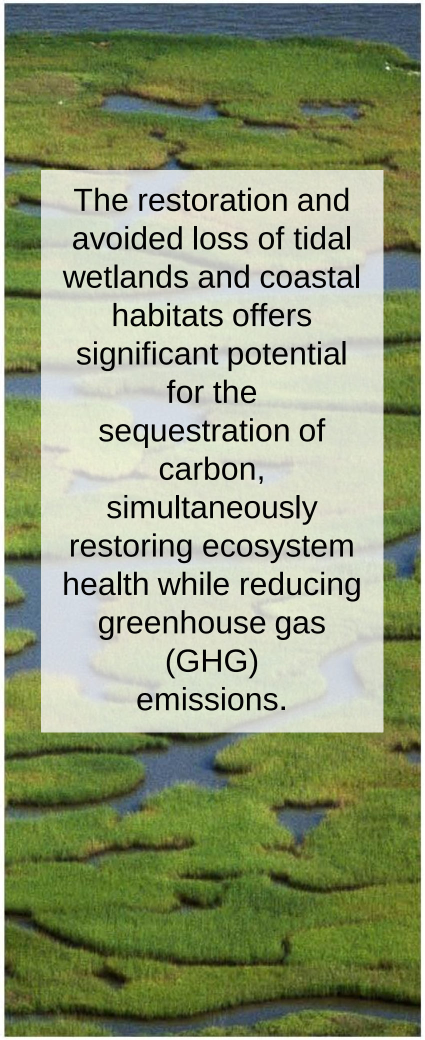


Figure 4. Mean accumulation rates of five parameters derived from six cores and aggregated by decade from year 1900 to 2010. All values based upon ^{210}Pb activity profile. Bars represent 95% confidence. Adapted from Breithaupt et al. 2014.



The restoration and avoided loss of tidal wetlands and coastal habitats offers significant potential for the sequestration of carbon, simultaneously restoring ecosystem health while reducing greenhouse gas (GHG) emissions.

Findings of the **National Blue Ribbon Panel** on the **Development** of a **Greenhouse Gas Offset** Protocol for **Tidal Wetlands** Restoration and Management

ACTION PLAN TO GUIDE PROTOCOL DEVELOPMENT

Based on a workshop convened by Restore America's Estuaries and held April 12-13, 2010

Prepared by Restore America's Estuaries, Philip Williams & Associates, Ltd., and Science Applications International Corporation.

August 2010

RESTORE AMERICA'S ESTUARIES

COASTAL BLUE CARBON

WETLANDS MITIGATING CLIMATE CHANGE

Coastal Blue Carbon is the carbon stored by and sequestered in coastal ecosystems, which include tidal wetlands, mangroves, and seagrass meadows.

Coastal Wetlands

These areas provide critically important ecological and economic values, such as habitat for important fish and other threatened and endangered species, storm and flood protection, improved water quality, tourism, and jobs, yet globally they are being lost at an unsustainable rate of **0.7-7% per year.**

3 Facts About Blue Carbon Ecosystems

Blue carbon ecosystems **remove 10 times more CO_2** per hectare from the atmosphere than forest.

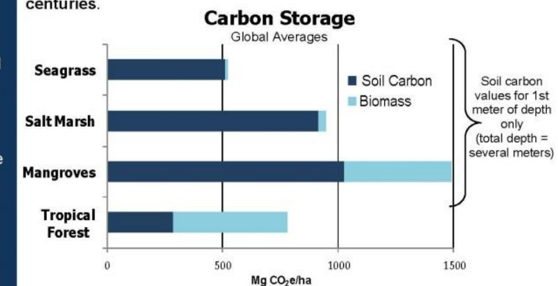
Wetlands primarily store carbon in the soils, where it can remain **for centuries.**

Drained and degraded coastal wetlands can release this stored carbon back into the atmosphere.

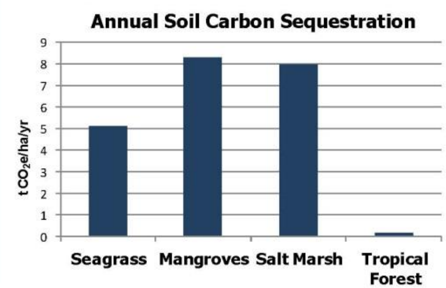
2014

The Science

Carbon is held in aboveground plant matter and wetland soils. As plants grow, carbon accumulates annually and is held in **soils** for centuries.



Each year an average of nearly half a billion tons of CO_2 (equal to the 2008 emissions of Japan) are released through wetland degradation, underscoring the need to **protect** our remaining wetlands.

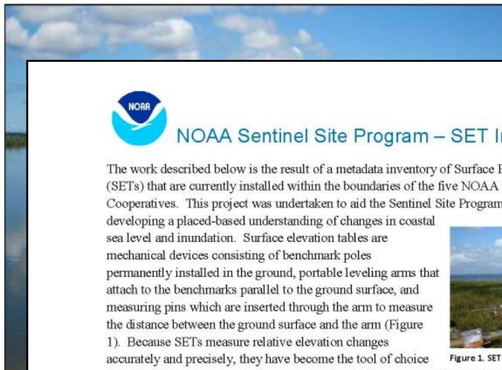


National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Protocol for Monitoring Coastal Salt Marsh Elevation and Vegetation Communities in Southeast Coast Network Parks

Natural Resource Report NPS/SECN/NRR—2015/985



NOAA Sentinel Site Program – SET Inventory

The work described below is the result of a metadata inventory of Surface Elevation Tables (SETs) that are currently installed within the boundaries of the five NOAA Sentinel Site Cooperatives. This project was undertaken to aid the Sentinel Site Program in its goal of developing a placed-based understanding of changes in coastal sea level and inundation. Surface elevation tables are mechanical devices consisting of benchmark poles permanently installed in the ground, portable leveling arms that attach to the benchmarks parallel to the ground surface, and measuring pins which are inserted through the arm to measure the distance between the ground surface and the arm (Figure 1). Because SETs measure relative elevation changes accurately and precisely, they have become the tool of choice for scientists and managers who are interested in the response of coastal wetlands to changes in relative sea level. These instruments have been installed throughout the coastal zone by researchers from government agencies, academic institutions, non-governmental organizations and private engineering and consulting firms. By identifying all of the SETs within a region and bringing together those who installed them, we are able to capitalize on existing resources to address questions about relative sea level rise over a broad geographic expanse with fine scale resolution. Further, this analysis lays the groundwork for strategic placement of future SETs to address gaps in current coverage.

Figure 1. SET with measuring pins

Database Development. At the beginning of this effort, one to two individuals with knowledge of local SET data were identified from each Sentinel Site (Figure 2). Collectively, this group agreed on the fields of data that would be included in the final database effort. After entering their own data, these individuals either contacted or provided contact information for other known SET owners in their regions. Every respondent was asked to provide further contacts and this type of word-of-mouth networking yielded the majority of our data. Additional data contacts were identified through advertising this effort at national professional meetings (Coastal and Estuarine Research Federation, National Estuarine Research Reserve System annual meetings) and through regional list serves. While the data gathered here may not be complete we feel confident that the vast majority of SET owners in each region has been identified and contacted.

We asked for information on all SETs within a region, not just those that are actively monitored. As a result, some of the SETs included in this analysis have not been measured for more than a decade. The amount of data submitted for each SET ranges from a simple

Figure 2 NOAA Sentinel Site Cooperatives

USGS science for a changing world

Patuxent Wildlife Research Center

Fire Island NS, NY USA

A: SET concepts and Theory:

- Surface Elevation Table
- Marker Horizons
- Shallow Subsidence

B: Types of SET devices:

- Original SET

Surface Elevation Table (SET)

by Donald R. Cahoon, Ph.D and James Lynch

The Surface Elevation Table (SET) is a portable mechanical leveling device for measuring the relative elevation change of wetland sediments. This website presents information on the purpose, design, and use of the SET. The website is specifically designed to be a forum for researchers in wetland science who use or might use the device and to offer more information about the proper use of the SET and interpretation of its data. But we encourage anyone who wants to learn more about research techniques and their development to visit the site as well.

Precise measures of sediment elevation in wetlands are necessary to determine rates of elevation change, particularly relative to sea level rise, and to gain an understanding of the processes responsible for elevation change. The SET provides a nondestructive method for making highly accurate and precise measurements of sediment elevation of intertidal and subtidal wetlands over long periods of time relative to a fixed ...

Coastal Wetlands Monitoring in the Southeast U.S.

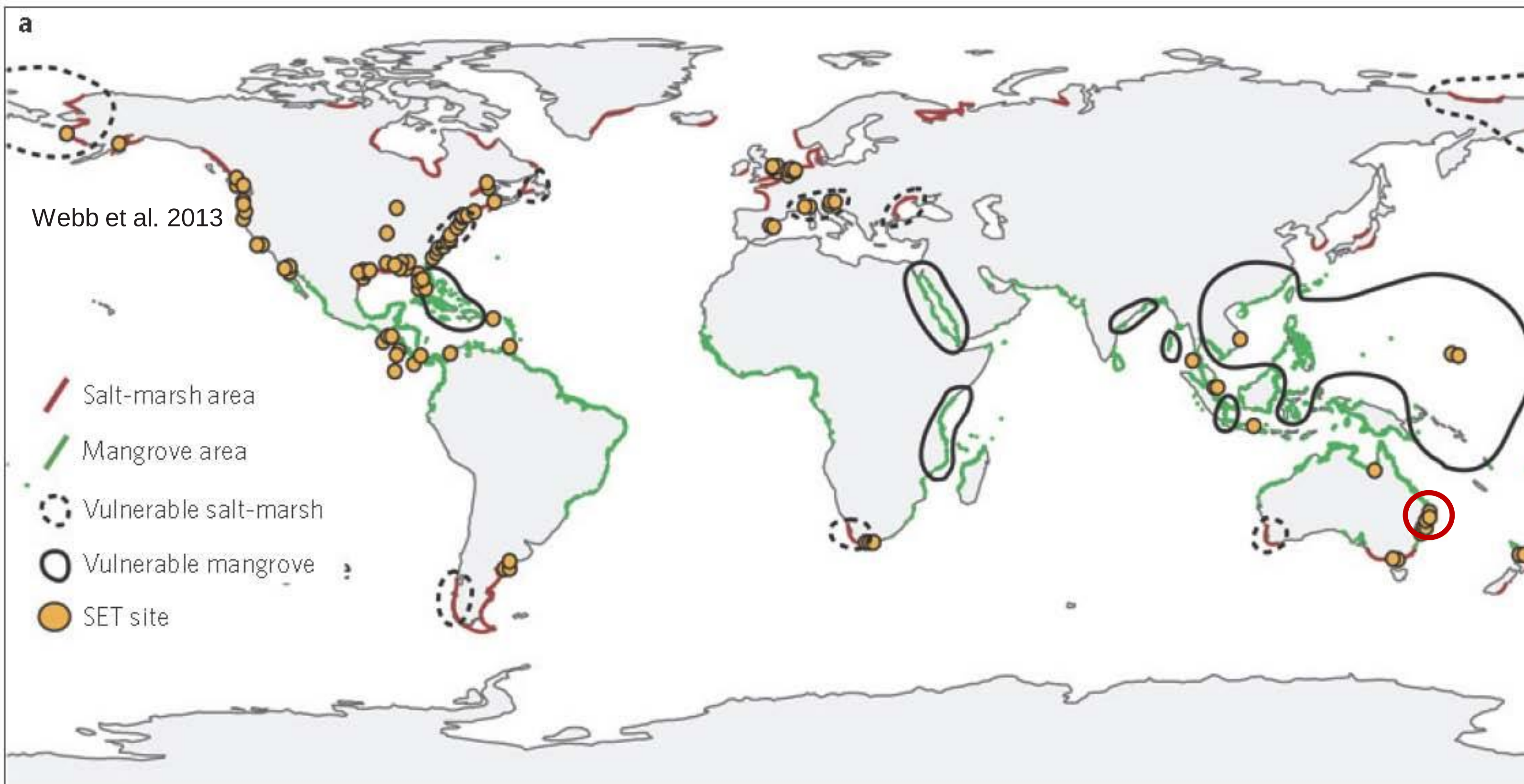
Governors' South Atlantic Alliance
North Carolina • South Carolina • Georgia • Florida

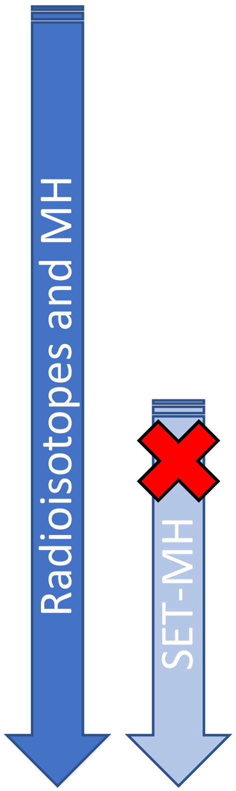
December 2016

Estuaries and Coasts (2014) 37:763–771
DOI 10.1007/s12237-013-9702-4

Contemporary Rates of Carbon Sequestration Through Vertical Accretion of Sediments in Mangrove Forests and Saltmarshes of South East Queensland, Australia

Catherine E. Lovelock · Maria Fernanda Adame · Vicki Bennion · Matthew Hayes · Julian O'Mara · Ruth Reef · Nadia S. Santini





Pilot studies and formulation of standard methods	Objective	Why
1970s and 80s	Above and below ground processes including biogeochemistry and sedimentation	How wetlands work
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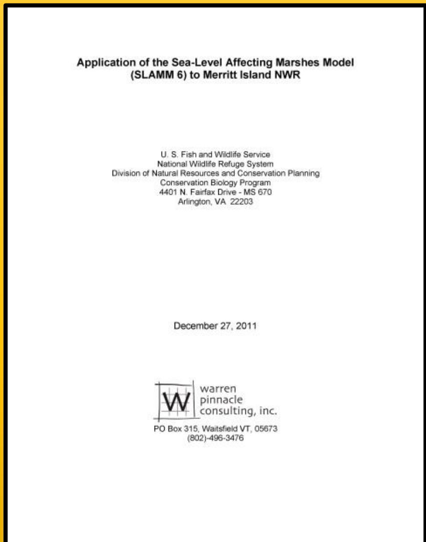
Mid-1990s and 00s	Recent sedimentation	R[illegible]iency (SLAMM) and restoration success (BACI)
2000s and 10s	C[illegible]on flux	Climate change

Evolution of approach and rationale used in wetland studies designed to quantify temporal and spatial changes in sedimentation

A logical progression of errors…..

Over the last decade, the UFSWS contracted SLAMM analysis of all 130+ coastal Refuges, including 22 in Florida.

I looked at four: Merritt Island, Archie Carr, Hobe Sound, and the Ten Thousand Island.


Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Merritt Island NWR

U. S. Fish and Wildlife Service
National Wildlife Refuge System
Division of Natural Resources and Conservation Planning
Conservation Biology Program
4401 N. Fairfax Drive - MS 670
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December 27, 2011

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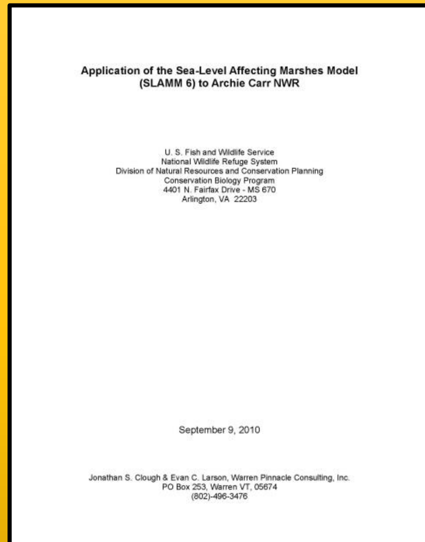
Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Archie Carr NWR

U. S. Fish and Wildlife Service
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September 9, 2010

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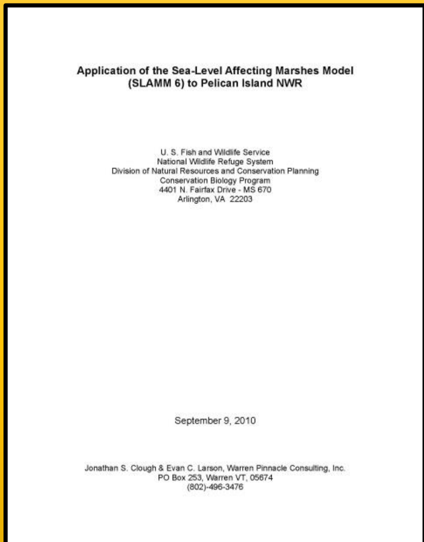
Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Pelican Island NWR

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September 9, 2010

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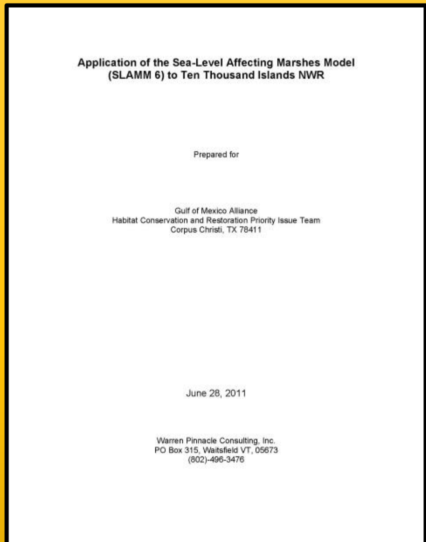
Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Ten Thousand Islands NWR

Prepared for

Gulf of Mexico Alliance
Habitat Conservation and Restoration Priority Issue Team
Corpus Christi, TX 78411

June 28, 2011

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Modeling of marsh and mangrove habitat response to SLR was often based upon SET data:

- Acquired from habitat different than the target Refuge
- Not collected in the State of Florida
- Inconsistent with references cited
- Or unrealistic default values

This yielded results that overestimated habitat resilience towards the year 2100.

Should (R)SET-MH data be used to forecast the effects of sea level rise on wetland resilience and carbon sequestration?

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