Texas Mangrove Research Symposium

Thursday, February 28
9:00am - 5:00pm
University of Texas Marine Science Institute
Estuarine Research Center, Seminar Room
750 Channel View Dr.
Port Aransas, Texas

AGENDA

9:00 - 9:15 **WELCOME AND INTRODUCTIONS**

9:15 - 9:30 **Dr. Kiersten Madden, Mission-Aransas National Estuarine Research Reserve**
Monitoring Mangroves: Applying the National Estuarine Research Reserve Approach to Texas

9:30 - 10:00 **Tom Tremblay, Bureau of Economic Geology, University of Texas at Austin**
Baseline Mapping for Mangrove Monitoring in the Coastal Bend, Texas Gulf Coast

10:00 - 10:30 **Dr. James Gibeaut, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University – Corpus Christi**
Proposed Observatory for Understanding Coastal Wetland Change

10:30 - 10:45 **BREAK**

10:45 - 11:15 **Dr. John Schalles, Creighton University**
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RD	Richard Day	USGS National Wetlands Research Center	dayr@usgs.gov
TD	Tom Doyle	USGS National Wetlands Research Center	Doylet@usgs.gov
RF	Rusty Feagin	Texas A&M University – College Station	feaginr@tamu.edu
JG	James Gibeaut	Texas A&M University – Corpus Christi	James.gibeaut@tamucc.edu
KK	Ken Krauss	USGS National Wetlands Research Center	kraussk@usgs.gov
KM	Kiersten Madden	Mission-Aransas National Estuarine Research Reserve	Kiersten.madden@utexas.edu
MO	Mike Osland	USGS National Wetlands Research Center	mosland@usgs.gov
SP	Steve Pennings	University of Houston	spennin@central.uh.edu
JS	John Schalles	Creighton University	Johnschalles@creighton.edu
LS	Liz Smith	International Crane Foundation	esmith@savingcranes.org
TT	Tom Tremblay	Bureau of Economic Geology – UT Austin	Tom.tremblay@beg.utexas.edu
EY	Erik Yando	University of Louisiana at Lafayette	Erik.yando@gmail.com
WORKSHOP PARTICIPANTS			
DA	Dan Alonso	San Antonio Bay Partnership	dalonso@sabay.org
KB	Karen Bishop	Texas Sea Grant	Karen.bishop@tamu.edu
JB	Jorge Brenner	The Nature Conservancy	jbrenner@tnc.org
EB	Ed Buskey	Mission-Aransas NERR	Ed.buskey@utexas.edu
RC	Rhonda Cummins	Texas Sea Grant	rcummins@tamu.edu
KD	Kelly Darnell	Univ. of Texas Marine Science Institute	kellymdarnell@gmail.com
ZD	Zack Darnell	Mission-Aransas NERR	mzd@utexas.edu
SD	Sayantani Dastidar	University of Houston	sayantanii@gmail.com
MAD	Mary Ann Davis	The Aquarium at Rockport Harbor	madradrpt@gmail.com
ND	Nicole Davis	Texas State University	ndavis@txstate.edu
RD	Richard Davis	Texas A&M University – Corpus Christi	Madradrpt@gmail.com
	Sarah Douglas	Univ. of Texas Marine Science Institute	sarahvdouglas@utexas.edu
CG	Catalina Gempeler	Univ. of Texas Marine Science Institute	catalicu@utexas.edu
HG	Hongyu Guo	University of Houston	greatuniverse@hotmail.com
BH	Beau Hardegree	US Fish and Wildlife Service	Beau_hardegree@fws.gov
WH	Wade Harrell	US Fish and Wildlife Service	Wade_harrell@fws.gov
KH	Kent Hicks	Texas Parks and Wildlife Department	Kent.hicks@tpwd.state.tx.us
LH	Lauren Hutchison	Texas A&M University – Corpus Christi	Lauren.hutchison@tamucc.edu
CH	Cammie Hyatt	Mission-Aransas NERR	Cammie.hyatt@utexas.edu
FK	Felix Keeley	City of Rockport/NERR Advisory Board	F_keeley@yahoo.com
	Ranjani Wasantha Kulawardhana	Texas A&M University – College Station	Wasanthkula@yahoo.com
JL	Jessica Lunt	Texas A&M University – Corpus Christi	jlunt@tamucc.edu
SM	Shanna Madsen	Mission-Aransas NERR	Shanna.l.madsen@gmail.com
DN	Duncan Neblett	Univ. of Texas Marine Science Institute	
DO	R. Deborah Overath	Texas A&M University – Corpus Christi	Deborah.overath@tamucc.edu
PR	Patrick Rios	City of Rockport Water Quality Committee	Prios1001@sbcglobal.net
JR	Jackie Robinson	Texas Parks and Wildlife Department	Jackie.robinson@tpwd.state.tx.us

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JS	James Sanchez	Texas A&M University – Corpus Christi	James.sanchz5484@sbcglobal.net
CPS	Carlota Plantier Santos	Harte Research Institute, Texas A&M University – Corpus Christi	Carlota.santos@tamucc.edu
CS	Chris Shank	Univ. of Texas Marine Science Institute	cshank@utexas.edu
JT	Jim Tolan	Texas Parks and Wildlife Department	James.tolan@tpwd.state.tx.us
KT	Kathryn Tunnell	Texas General Land Office	Kathryn.tunnell@glo.texas.gov
HW	Heather Wade	Texas Sea Grant/Mission-Aransas NERR	hbwade@tamu.edu
CW	Carolyn Weaver	Texas A&M University – Galveston	caweaver@tamug.edu
DW	Dawn Whitehead	US Fish and Wildlife Service	Dawn_Whitehead@fws.gov
AW	Ashley Whitt	Texas A&M University – Galveston	whitta@tamug.edu
LW	Leslie Williams	Texas Parks and Wildlife Department	Leslie.williams@tpwd.state.tx.us
DY	David Yoskowitz	Harte Research Institute, Texas A&M University – Corpus Christi	David.yoskowitz@tamucc.edu

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HG	Hongyu Guo	University of Houston	greatuniverse@hotmail.com
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Discussion Notes

Liz Smith: Mangrove research needs to concentrate on finding funding that will allow for more information on the types of species that will be impacted by the conversion of salt marsh to mangrove structure; specifically, we need to figure out what will happen with snails, crabs, fish, etc. to get a handle on if the food web will shift, and how.

Liz Smith: Research into the potential impact of mangrove establishment higher in the estuary, given that we will have diminishing freshwater inflows (due to climate change, water use, etc.). We already have a narrow band of intermediate marsh, and a lower brackish area. If we lose that, will we have mangroves all the way into the delta? We need to look at the diversity of the system with regard to the replacement of marshes along the salinity gradient.

Michael Osland: We have a proposal into the Climate Science Center to quantify the relationship between precipitation and temperature on a gradient from the Florida/Alabama border to Mexico. At Liz's suggestion, we will look into making the Mission-Aransas and San Antonio bay systems Texas priority sites.

Kiersten Madden: There is a Gulf workgroup forming for mangroves – would it be possible to form a Texas working group?
Tom Tremblay: It might be a good idea to host a special session in conjunction with the 2014 Texas Bays and Estuaries meeting.

Rusty Feagin: What's the general consensus on mangrove expansion? If we were going to restore a site, would you plant mangroves?
Anna Armitage: We can't answer that question yet, because we don't know enough about the implications, costs, and what you gain or lose when you use mangroves in restoration projects. This is a broad area for future research – understanding how to manage these resources in response to mangrove expansion.

Liz Smith: I don't think that we should take mangroves out of the equation if we don't have a good understanding of the impacts yet. We also shouldn't be putting these opinions into our research designs. The public may have one opinion regarding mangrove expansion, but we don't know, and mangrove expansion may be something that we cannot change at all. With regard to whooping cranes, we want to know quantitatively and scientifically what the answer is. However, we need it soon, and we may have to make some management decisions before all of those answers are known.

Jim Gibeaut: I want to emphasize Liz's point about the fact that we may not be able to stop mangrove expansion. There are some good points to mangrove expansion: based on data from Rusty and others, the sedimentation rate from mangroves is higher than *Spartina*, and therefore they should be able to keep up with sea level rise better than marshes. Given the future rates for sea level rise, it might be a question of whether we have any kind of vegetation habitat rather than

simply open water. Having mangroves in the mix might maintain that intertidal vegetation habitat. More research is needed on mangrove expansion in the face of sea level rise and sedimentation.

Chris Wilson: People don't necessarily see mangroves as a positive thing – they see mangroves as an invasive species. The ecotone is changing, and mangroves don't directly cause the loss of salt marsh.

Lauren Hutchison: We've conducted focus groups and based on those preliminary results, people don't know what mangroves are, and the only ones who do are recreational users of those areas.

Rusty Feagin: What about restoration managers? We are making large changes in physical landscape by agencies completing restoration projects (mitigation banks, etc.); there is a fair amount of wetland created. It could be possible that the ecosystem services from using mangroves are higher – maybe those services make the use of mangroves a net positive.
Beau Hardegree: That might be the case, but we shouldn't be too hasty and put mangroves in all of our restoration projects. In the past, when mitigation occurs we haven't used mangroves because mitigation is usually completed in perpetuity – mangroves freeze. New research is showing that mangroves don't freeze and die off completely as previously thought, so we are looking at mangrove restoration as an option. However, we need to think about where we're placing them – maybe they shouldn't be planted in Whooping Crane habitat.

John Schalles: No one has brought this up yet, but does the expansion of mangroves present issues for human health and an increase of vector-borne diseases? Are there any implications for avian health? There is currently no research being done on this.

Tom Tremblay: There was a previous planting effort in Bajilla Grande when it was realized that Mother Nature was spreading mangroves better than any planting could. Maybe we don't need to be promoting restoration projects using mangrove, because it will happen anyhow; if we have a choice, maybe we should plant *Spartina*.
Kiersten Madden: Do restoration practitioners know this?
Beau Hardegree: There's a recent feeling that people are using mangroves for in-kind projects.
Kiersten Madden: Does that responsibility fall to you to make those decisions?
Beau Hardegree: Resource management agencies and the Army Corps of Engineers normally make the decision.
Kiersten Madden: We need a representative from the Corps here.

Tom Tremblay: Future research might look into morphology classifications (clumps, singular, linear formations along inlets) to determine if certain forms are less intrusive than others. We are also currently focusing a lot on Harbor Island, which could possibly be a unique case because of its origin as a relic-ed tidal fan delta, which is unusual for the proliferation of mangroves. There are other forms of expansion (linear, etc.) found elsewhere. We need more research in general, not just here in Harbor Island.

Monitoring Mangroves

APPLYING THE NERRS APPROACH IN TEXAS

Kiersten Madden
Stewardship Coordinator
Mission-Aransas National Estuarine Research Reserve

National Estuarine Research Reserve System

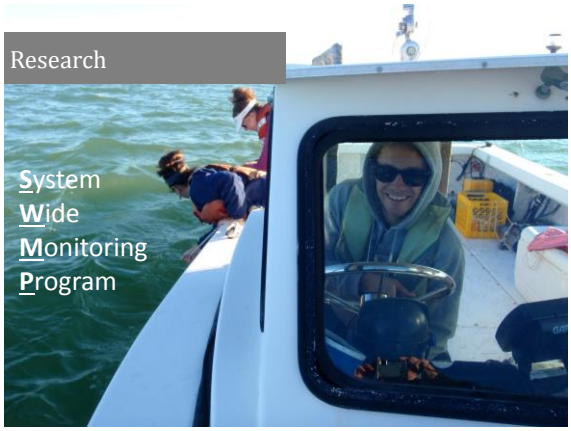
Mission-Aransas Reserve

The Mission-Aransas NERR brings together scientists, landowners, policy-makers, & the public to ensure that coastal management decisions benefit flora & fauna, water quality, and people.

Sectors

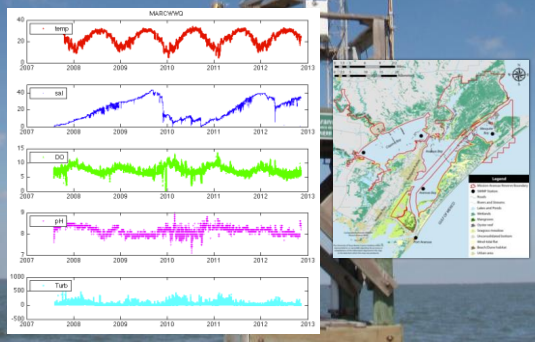
RESEARCH	STEWARDSHIP	EDUCATION	TRAINING
			
Improve understanding of Texas coastal zone ecosystem structure and function	Promote public appreciation and support for stewardship of coastal resources	Increase understanding of coastal ecosystems by diverse audiences	Increase understanding of coastal ecosystems by coastal decision makers

Research

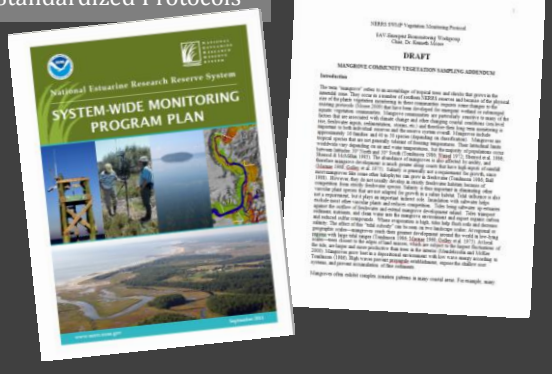


System
Wide
Monitoring
Program

System Wide Monitoring Program



Standardized Protocols

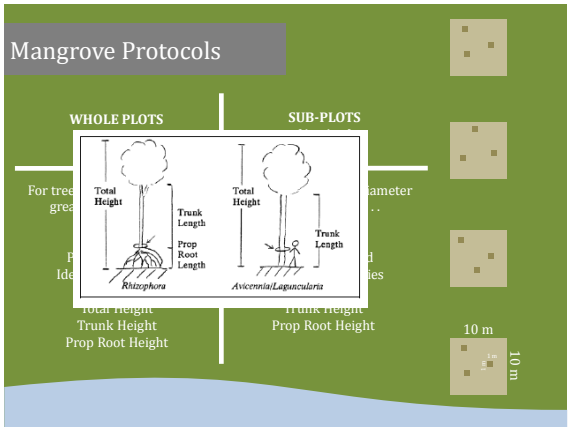


Vegetation Monitoring Protocol

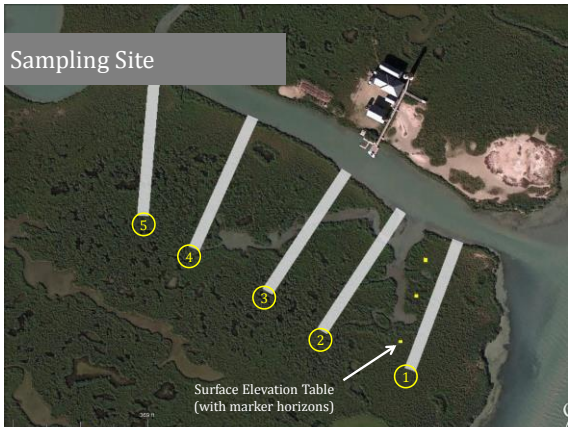
The NERRS monitoring protocol for vegetation communities is designed to:

1. Quantify vegetation patterns and their change over space and time;
2. Be consistent with other monitoring protocols used nationally and worldwide;
3. Be consistently used over a wide range of estuarine sites and habitats, and for a variety of reserve specific purposes;
4. Be used as a foundation for quantifying relationships among the various edaphic factors and the processes that are regulating the patterns of distribution and abundance in these communities;
5. Provide detailed information that can be used to support comprehensive remotely sensed mapping of vegetation communities and other NERRS System Wide Monitoring Program data collection, as well as NERRS/NOAA education, stewardship and restoration efforts.

Mangrove Protocols



Sampling Site



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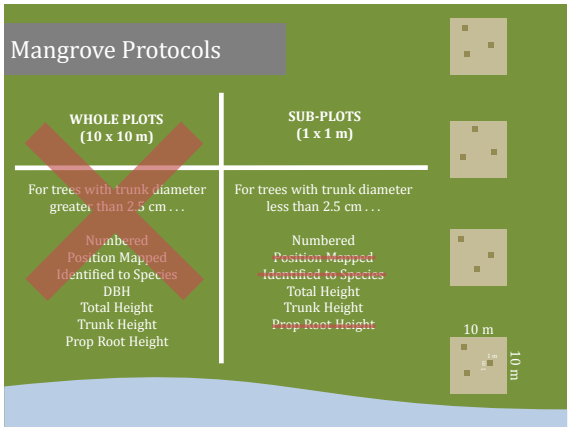
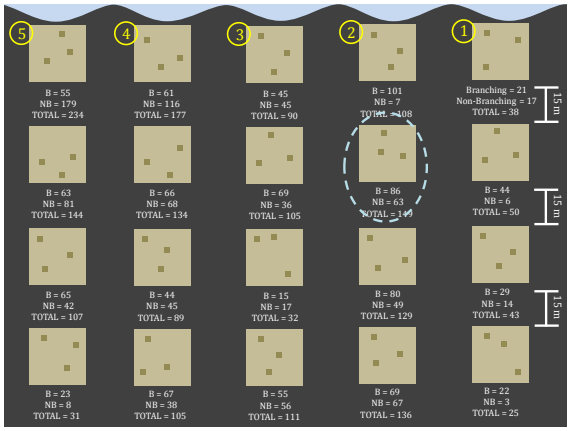
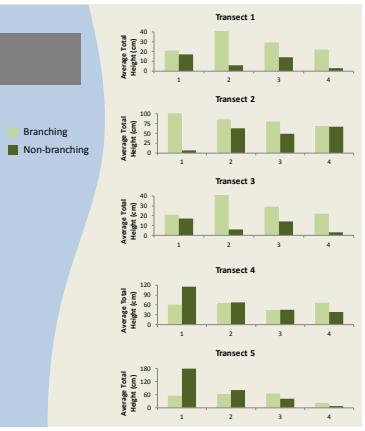




Total Height

Trunk Height



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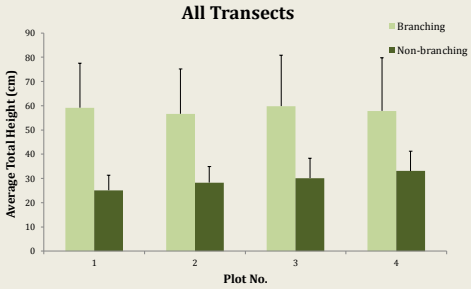

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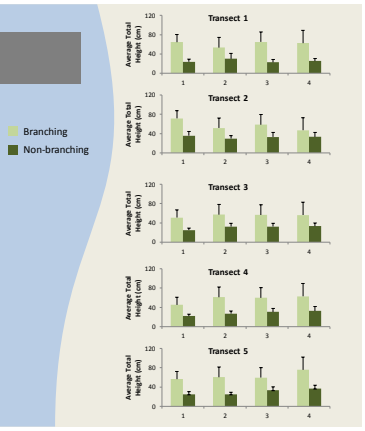

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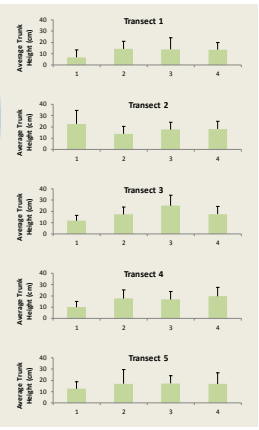
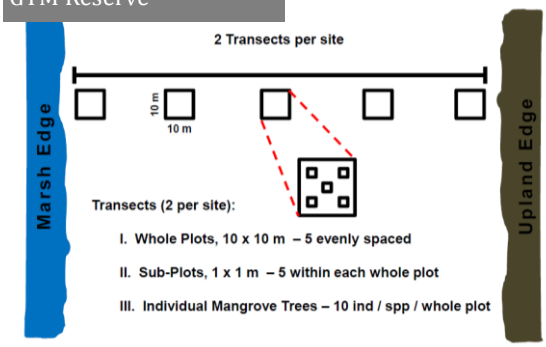


GTM Reserve



GTM Reserve

WHOLE PLOTS (10 x 10 m)	SUB-PLOTS (1 x 1 m)	TREE ARCHITECTURE (10 ind / spp / whole plot)
1. Percent Cover 2. Temperature (Soil Porewater) 3. Salinity (Soil Porewater)	1. Total Count - Mangrove Spp 2. Form (shoot vs. tree) 3. Trunk Diameter 4. Canopy Height 5. Percent Cover	1. Canopy Height 2. Trunk Formation 3. Trunk Diameter 4. Clear Height 5. Canopy – Wide Axis 6. Canopy – Narrow Axis 7. Canopy Offset 8. Ground Cover
n = 5 per transect	n = 5 per whole plot	

What's the best approach?

Is annual monitoring sufficient?

Do we need to be monitoring this many "individuals"?

Is the GTM approach better suited for this type of mangrove habitat?

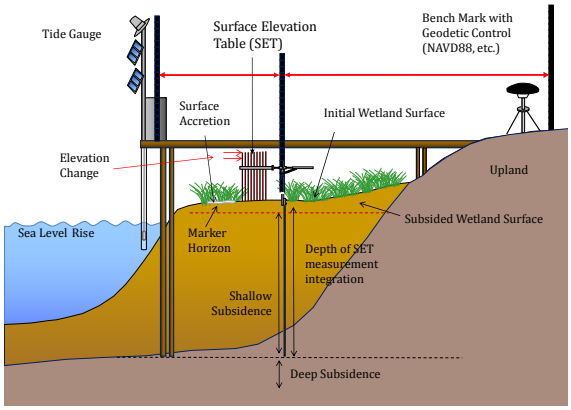
Kiersten Madden, Ph.D.
Stewardship Coordinator
Mission-Aransas NERR

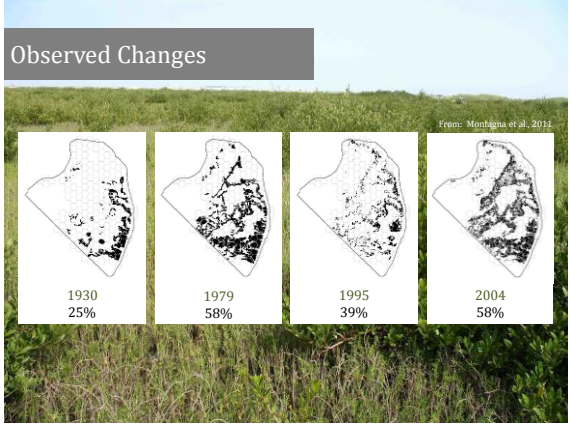
361-749-3047
kiersten.madden@utexas.edu

www.missionaransas.org

Sentinel Sites

Focused on understanding changes in sea level and inundation and the associated responses of marsh, mangrove, and submerged aquatic vegetation.


Tide Gauge
Surface Elevation Table (SET)
Bench Mark with Geodetic Control (NAVD88, etc.)
Surface Accretion
Initial Wetland Surface
Elevation Change
Upland
Subsided Wetland Surface
Sea Level Rise
Marker Horizon
Depth of SET measurement integration
Shallow Subsidence
Deep Subsidence


Observed Changes
From: Montagna et al., 2011
1930
25%
1979
58%
1995
39%
2004
58%

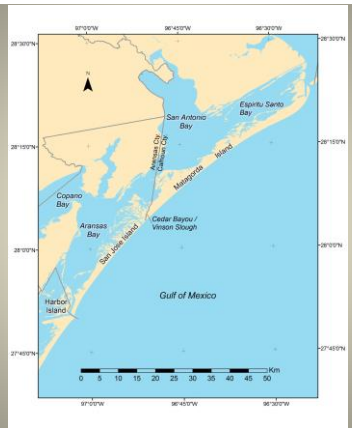
Baseline Mapping for Mangrove Monitoring in the Coastal Bend,

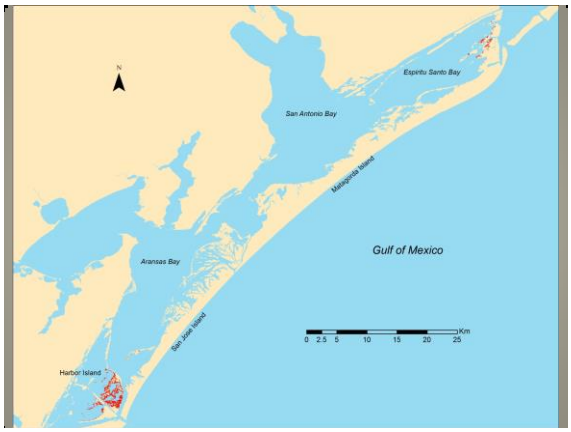
Texas Gulf Coast

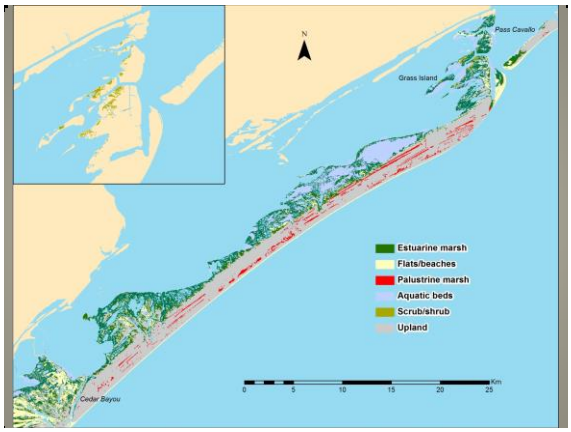
Thomas A. Tremblay
Bureau of Economic Geology, UT

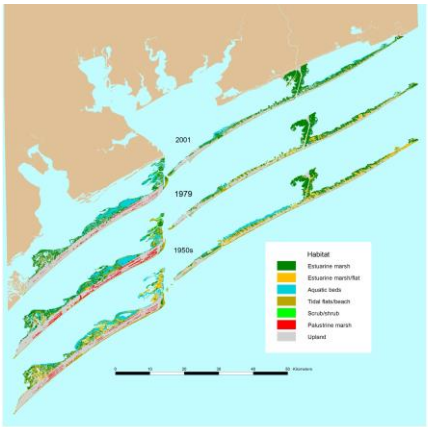
Amy L. Neuenschwander
Applied Research Laboratories, UT

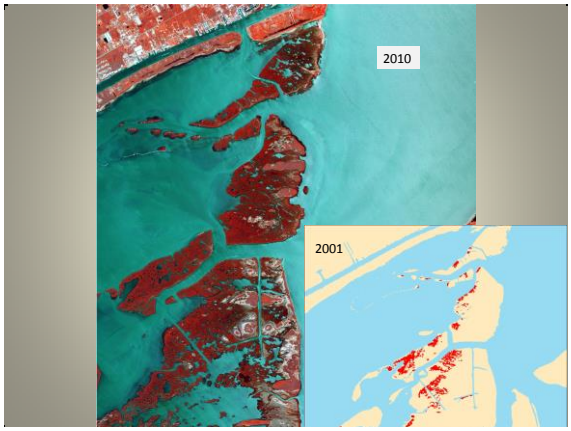
Daniel Gao
Texas General Land Office

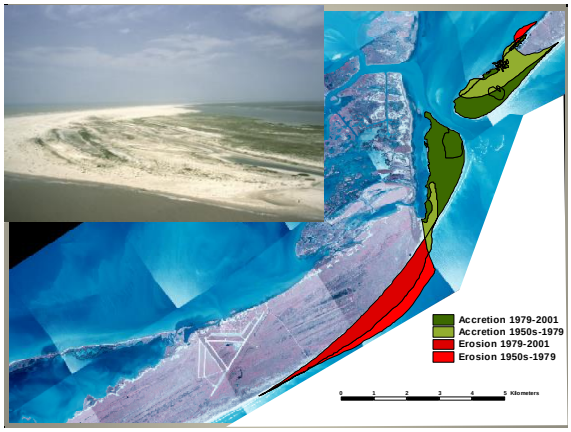


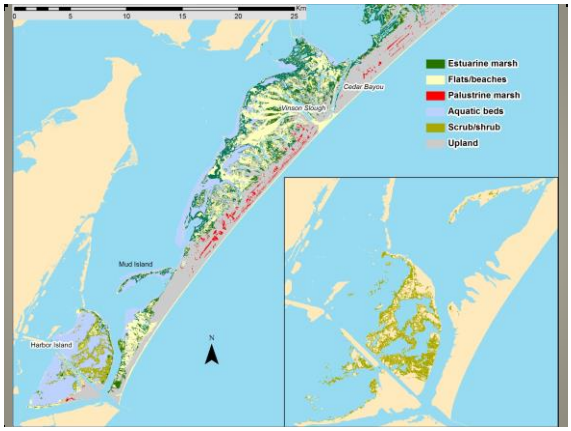


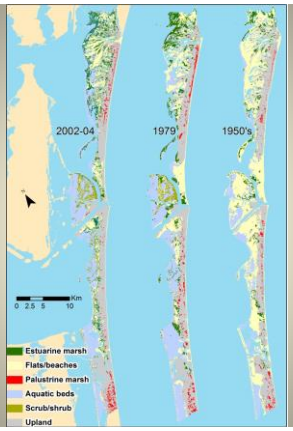


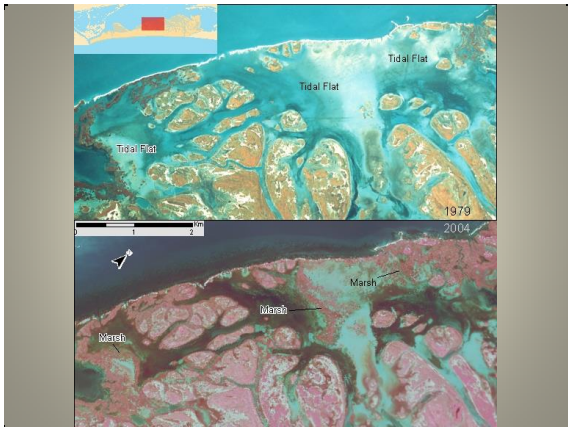


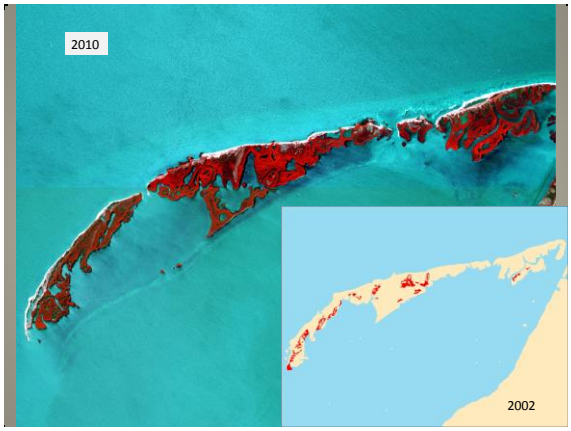


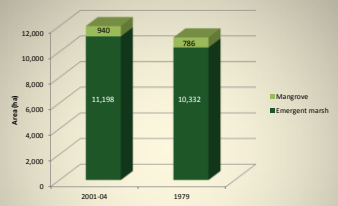

Accretion 1979-2001
Accretion 1950s-1979
Erosion 1979-2001
Erosion 1950s-1979
Kilometers


Estuarine marsh
Flats/beaches
Palustrine marsh
Aquatic beds
Scrub/shrub
Upland
Cedar Bayou
Mission Slough
Mud Island
Harbor Island
N


2002-04
1979
1950's
Estuarine marsh
Flats/beaches
Palustrine marsh
Aquatic beds
Scrub/shrub
Upland


Tidal Flat
Tidal Flat
Tidal Flat
1979
2004
Marsh
Marsh
Marsh

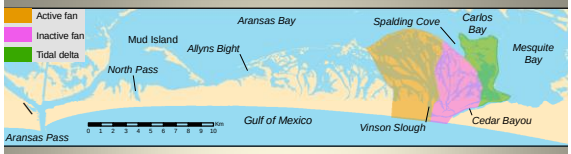

2010
2002



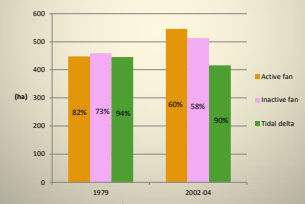
Change rate

Mangrove +7 ha/yr

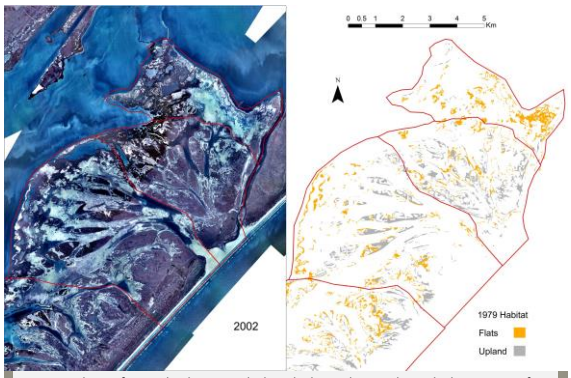
Emergent marsh +38 ha/yr



after Andrews, 1970



Salt marsh in fan/delta complex (% low marsh)



Some marsh gain from uplands occurred where high marsh moved into the lower parts of eolian mounds. Eolian mounds are elongate sand mounds that occupy the interdistributary areas of the washover fan (Andrews, 1970).

Range: 350 to 2500 nm
Spectral resolution: 3 nm @ 700
Sampling interval: 1.4 nm @ 350 – 1000 nm
Speed: 0.2 seconds/ spectrum

HyperScan-VNIR-micro (16 bit camera)
Detector size: 2400 x 2400 spatial pixels
HyperVision software: ENVI-IDL + flight data capture system with SSD
Spectral range: 0.4 to 0.1 µm

Conclusions

- Salt marsh and mangroves have been increasing in area since the mid-1950's with marshes increasing at higher rates
- Within the washover fan/tidal delta complex on San Jose Island, marsh is expanding with a net loss of low marsh and a net increase of high marsh
- Wetland change is probably caused by relative sea level rise where low marsh is inundated and high marsh moves into flats or upland

Summary

- Focus on Matagorda Island and San Jose Island
- Dynamic area affected by sea-level rise and erosion/accretion, with wetland trends similar to those found on much of the Lower Texas Coast
- Objective is to establish methods and protocol for automated mangrove monitoring using the hyperspectral platform

The End…?

The Order of the Straight Arrow

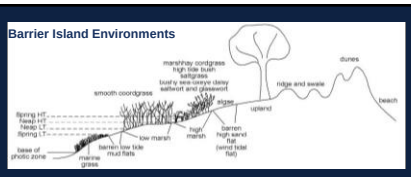
Season 1, episode 3

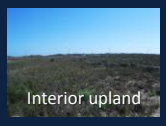
Proposed Observatory for Understanding Coastal Wetland Change

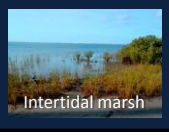
James Gibeaut

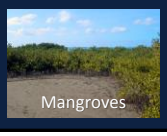
Harte Research Institute for Gulf of Mexico Studies

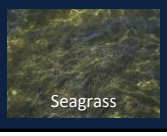
Texas A&M University – Corpus Christi



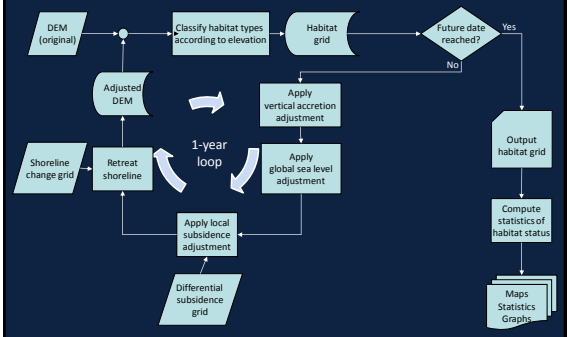




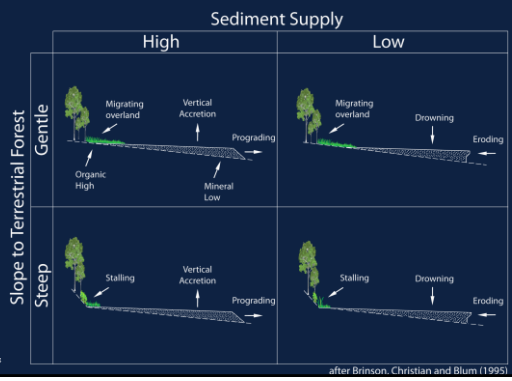




Wetland Transition Model

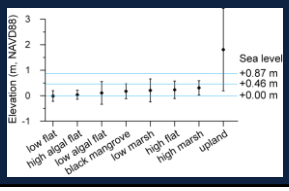


Wetland Response to Sea Level Rise

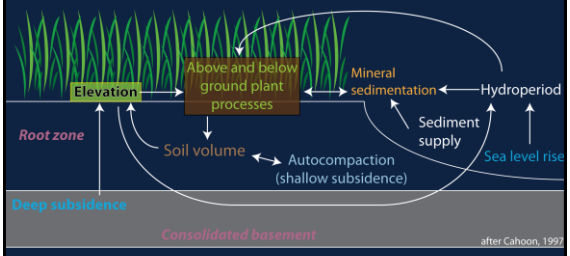


after Brinson, Christian and Blum (1995)

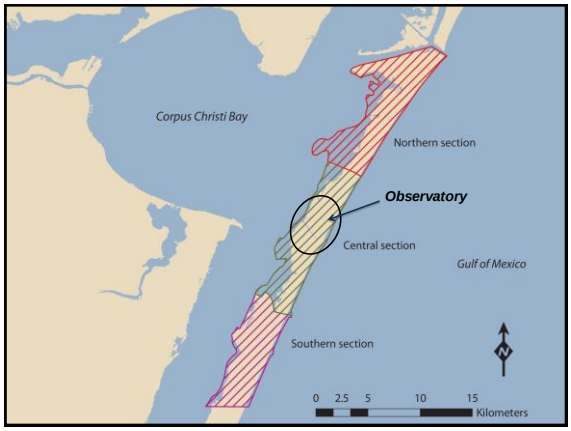
Topographic relationship of habitat types



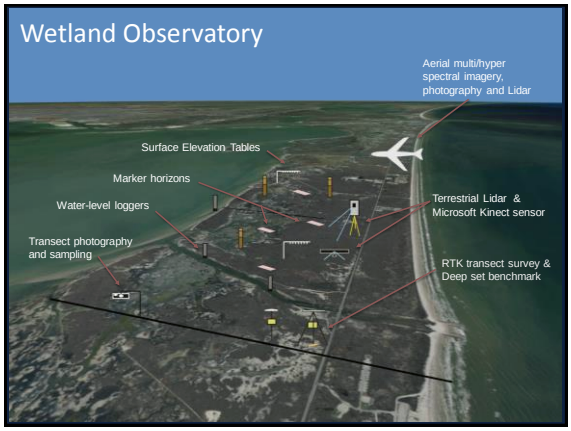
Processes Affecting Marsh Elevation



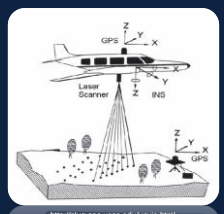
after Cahoon, 1992



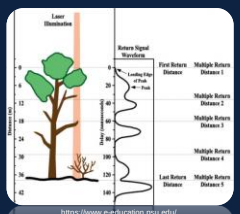
Wetland Observatory



Airborne lidar for topographic mapping

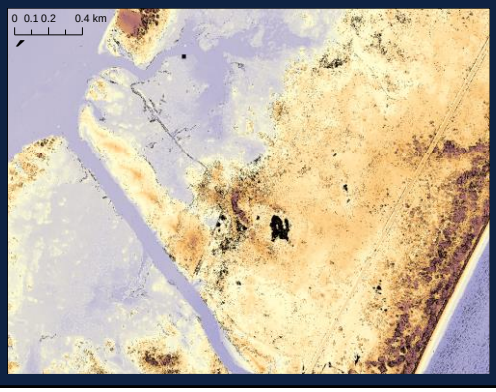


http://slvg.soe.ucsc.edu/urvis.html



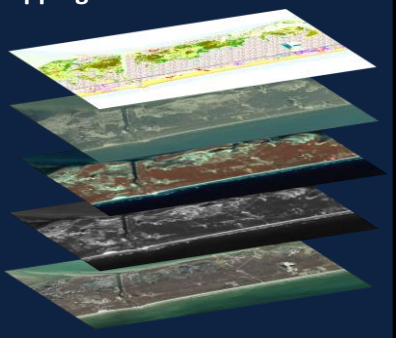
https://www.e-education.psu.edu/

Detection and removal of shrubs and building



Vegetation mapping

- Aerial photography
- Multi/hyperspectral



Elevation control: deep set benchmarks

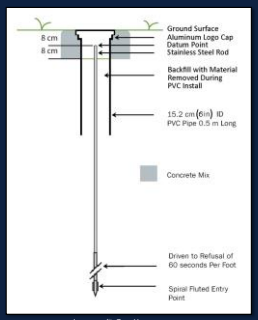
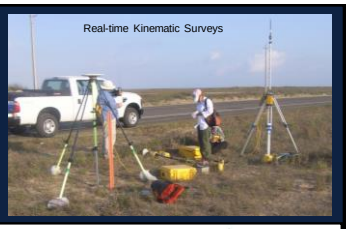
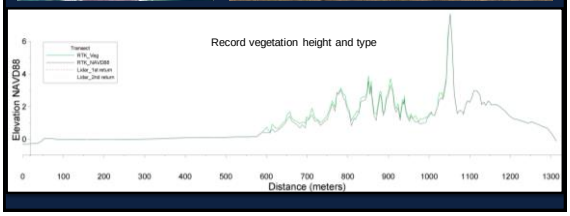
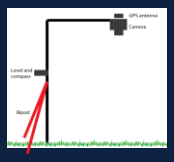


Image credit: Greg Hauger

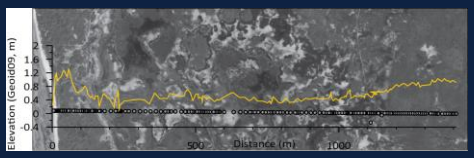


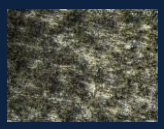


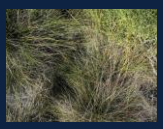


Transect monitoring of wetland vegetation change

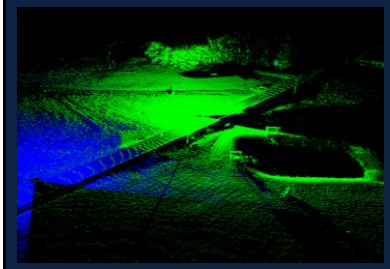
Transect monitoring of wetland vegetation change



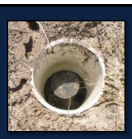


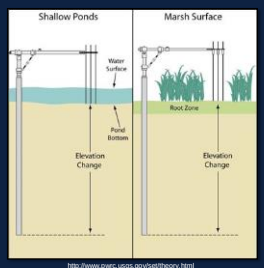


Terrestrial Laser for topographic mapping



Surface Elevation Tables (SET) for measurement of elevation change





http://www.pwrc.usgs.gov/set/theory.html

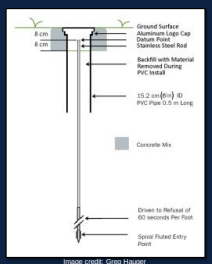
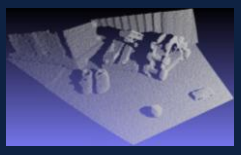


Image credit: Greg Hauger

Future Exploration: low-cost lidar sensor

Microsoft Kinect

- IR projector & camera for depth map
- 30 cm to 15 m range
- Spatial resolution ~7 mm at 5 m
- Cheap < $150; open source tools



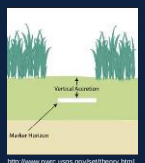
Potential Metrics

- Micro-topography time series
  - mount along transect
- Water inundation
  - Near-IR & RGB camera

Challenges

- Field deployment
  - power, environmental conditions
- Will change signal be detectable?
  - mm-level
- Telemetry

Marker horizons for measurement of sedimentation rates



http://www.pwrc.usgs.gov/set/theory.html

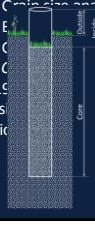
http://www.pwrc.usgs.gov/set/theory.html

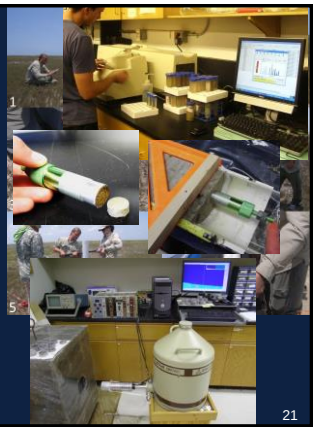
Marker horizon locations

Total of 168 Marker Horizons

Coring for accretion measurements

- **Field Methods**
  - Coring & compaction
  - GPS observations
- **Lab Methods**
  - Grain size analysis
  - E
  - C oscopy
  →C 7
  - 19 rizon due to
  res eric fallout
  pri lear test ban

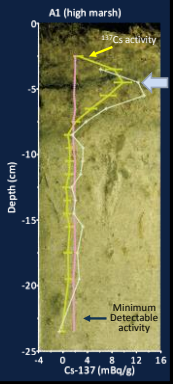




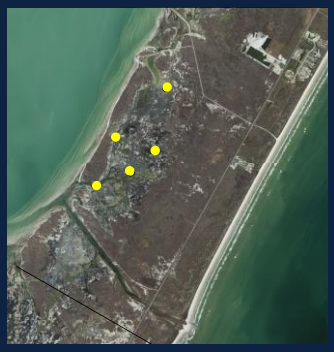
Accretion Rate Calculation

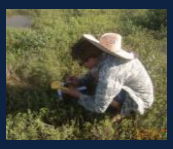
$$\text{Accretion Rate} = \frac{\text{Depth to 137Cs Peak}}{\text{Years since 1963}}$$

- Is 1963 peak present and above minimum detectable activity (is it really there)?
- Correct peak depth for grain size influence
- Correct peak depth for core compaction

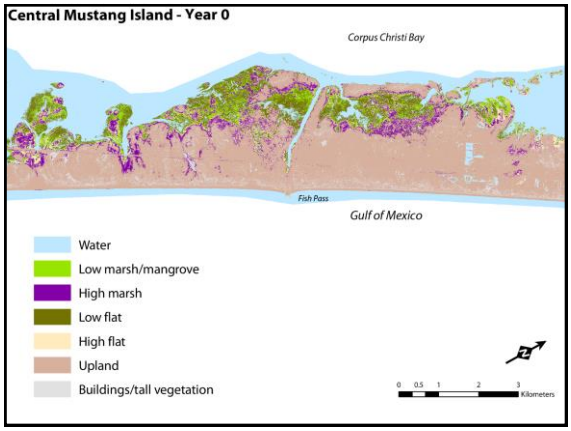


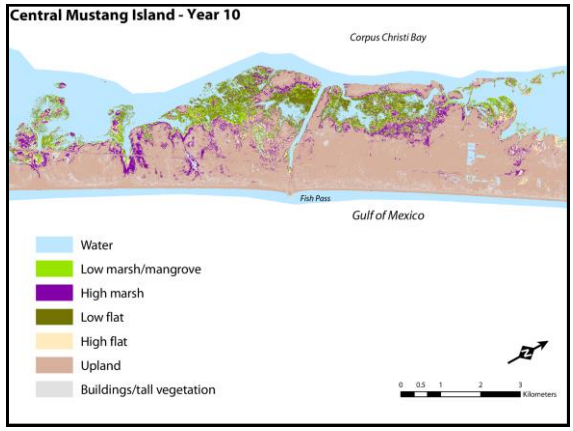
Water-level measurements

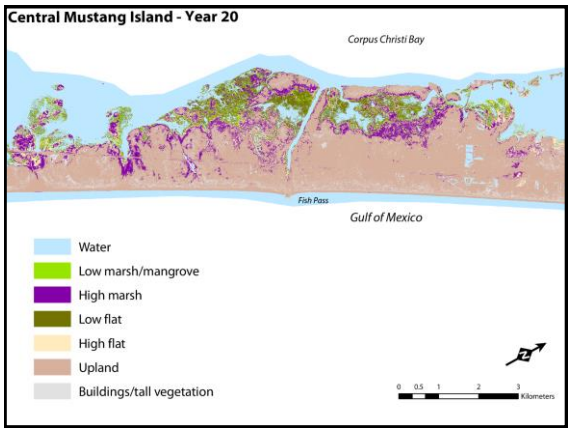


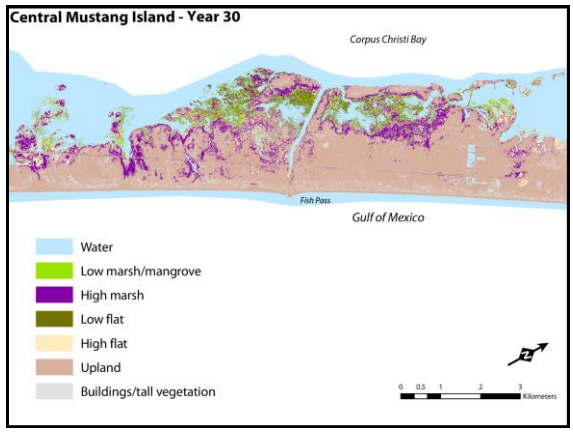


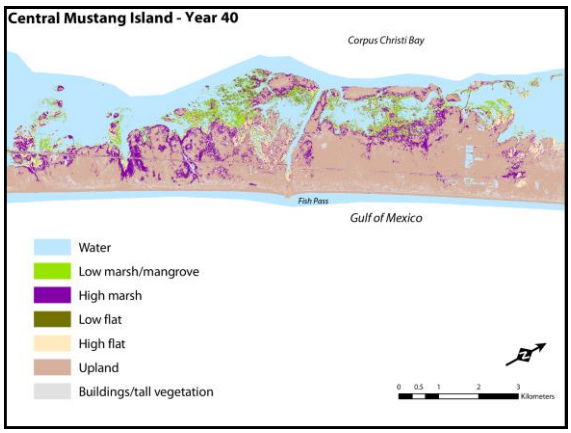
Wetland Observatory

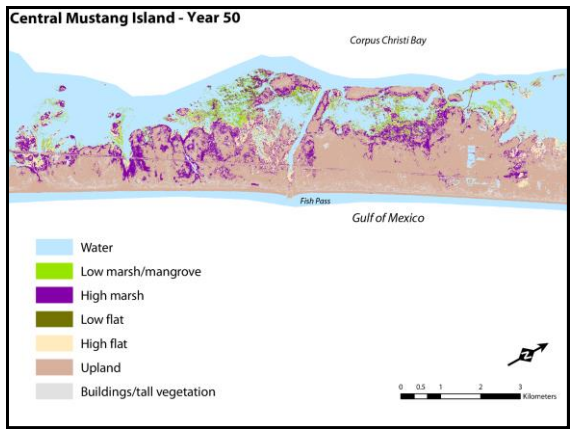

Central Mustang Island - Year 0
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers

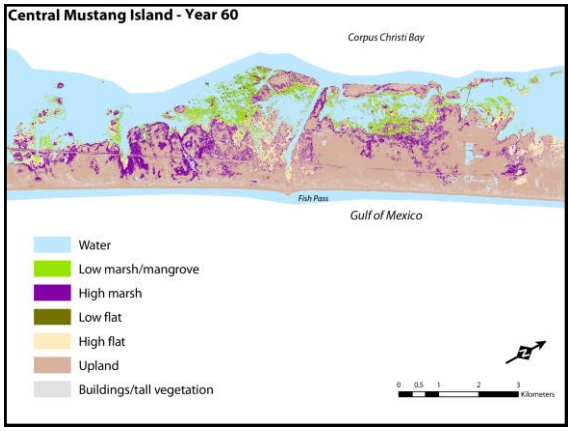

Central Mustang Island - Year 10
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers

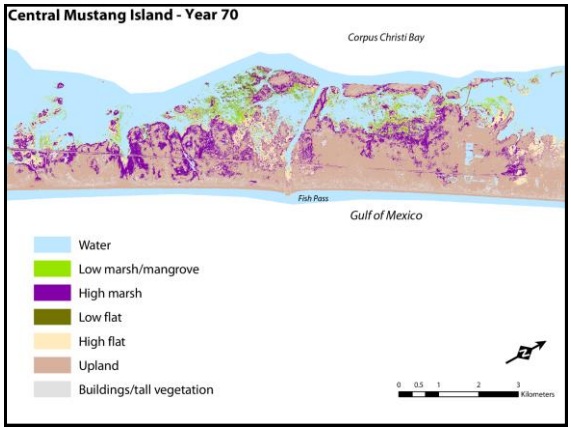

Central Mustang Island - Year 20
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers

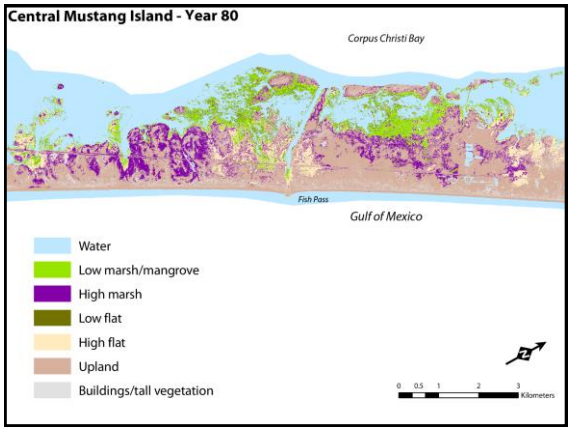

Central Mustang Island - Year 30
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers

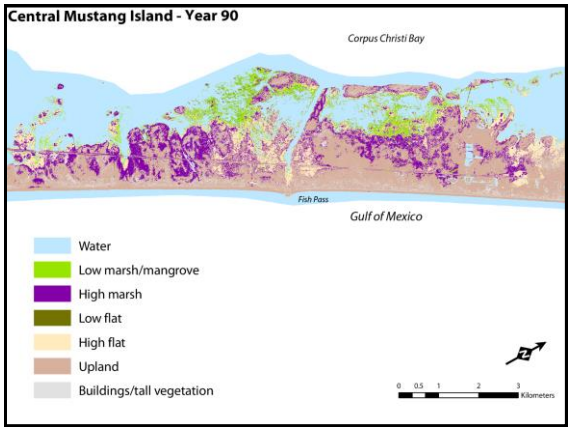

Central Mustang Island - Year 40
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers


Central Mustang Island - Year 50
Corpus Christi Bay
Fish Pass
Gulf of Mexico
Water
Low marsh/mangrove
High marsh
Low flat
High flat
Upland
Buildings/tall vegetation
0 0.5 1 2 3
Kilometers

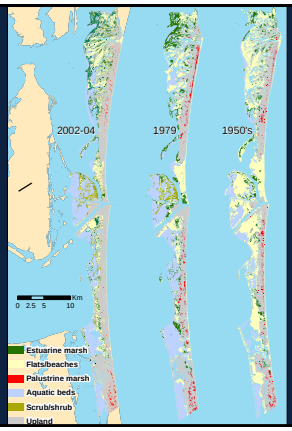






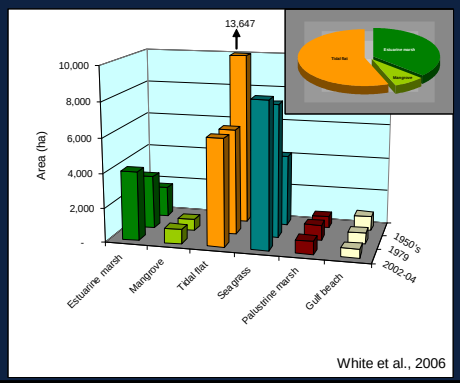


Wetland Distribution



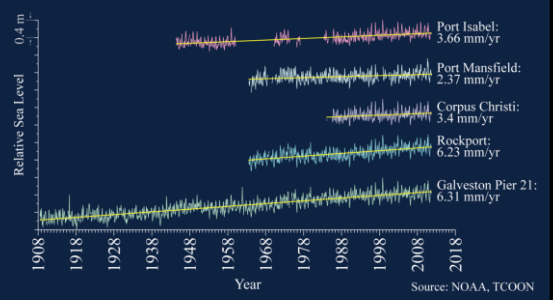
White et al., 2006

Wetland Change – Coastal Bend



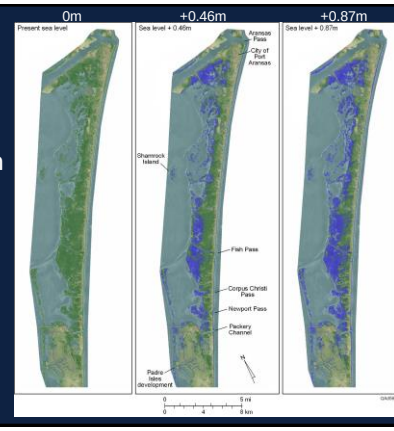
White et al., 2006

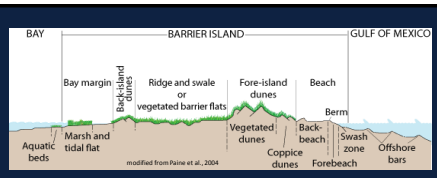
Relative Sea-level Rise

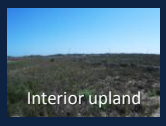


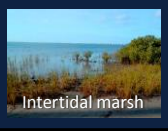
Mustang Island Inundation by Year 2100

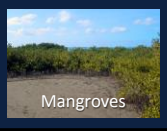
Based on IPCC (2007) sea-level rise projections plus local land subsidence estimate

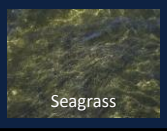


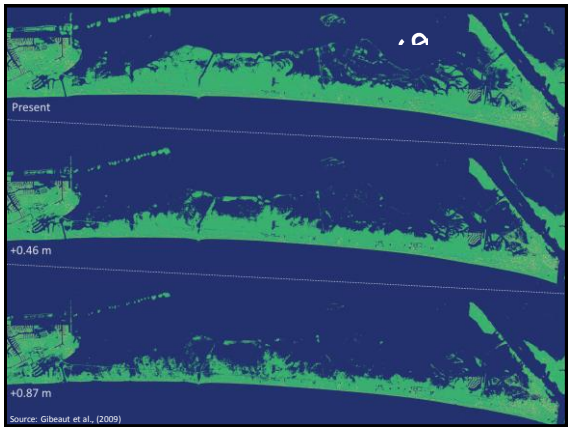




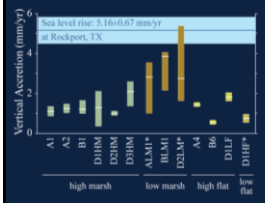






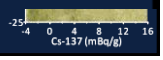


Accretion Rate Calculation



	mm yr^{-1}
High marsh accretion	1.4
Low marsh accretion	3.2
High flat accretion	1.3

- Accretionary deficit makes wetland susceptible to submergence
- Higher environments at higher risk
- <u>Marsh</u> accretion is directly correlated with elevation



The Mangroves of Redfish Bay: Field Surveys and High Resolution Imagery to Map Distribution, Canopy Height, and Vegetation Response to the February, 2011 Freeze

John Schalles[1], Alissa Hart[2],
Adam Altrichter[3], and Eryn Carpenter[1]
[1]Creighton University, Omaha, NE
[2]Loyala University, Chicago, IL
[3]Virginia Tech, Blacksburg, VA

JohnSchalles@creighton.edu

We're Pleased to Acknowledge Help From:

• Field Surveys: Anna Armitage, Wayne Carpenter, Tyler Craven, Kiersten Madden, Shanna Madsen, Tyler Monahan, John O'Donnell, John Olley, Drew Seminara, Liz Smith

• AISA Eagle hyperspectral imagery and initial processing: Rick Perk, Paul Merani & Don Rundquist (CALMIT – Univ. Nebraska); Jeffrey Vincent (University of Texas – Austin)

•Field logistics, and explanations of Texas coastal ecology: Sally Morehead, Kiersten Madden, Dennis Pridgen, Liz Smith, Wes Tunnell, John Woods, Ed Zielinski, Captain Frank

• Financial and logistical support: NOAA-NCCOS Environmental Cooperative Science Center, Texas Parks and Wildlife, Mission-Aransas NERR, University of Texas Marine Science Institute, NASA Nebraska Space Institute

Drag the icons to Re-Order Your Stops
A Omaha, NE
B Corpus Christi, TX
C Pascagoula, MS
D Omaha, NE
Prefer separate address forms?
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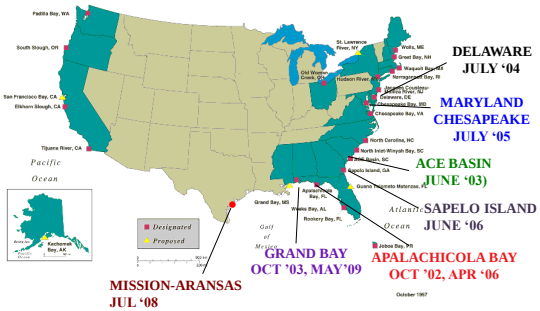
Your trip is 43 hours 48 minutes / 2752.56 miles (view in km)
Directions Options
Save to My Maps

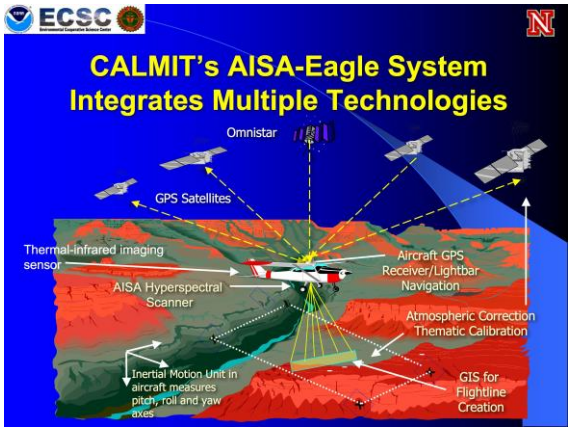
Spring Break Research Trip:
- Depart Omaha early AM Sat, Mar 5
- First night lodging ~ North Texas
- Arrive Port Aransas, TX in PM, Sun, Mar 6
- Field work at Mission-Aransas NERR from Mon, Mar 7 to Thurs, Mar 10 and housing (tentative) at U.T Marine Inst. apartment
- Drive to Grand Bay, MS on Fri, Mar 11 drop boat off, overnight stay at GB NERR
- Depart in AM on Sat, Mar 12
- Last night lodging ~ SE Missouri
- Arrive back in Omaha in early evening on Sunday, March 13

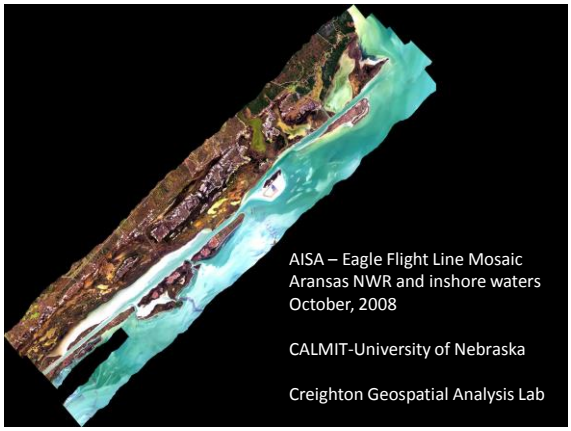
Outline for My Presentation

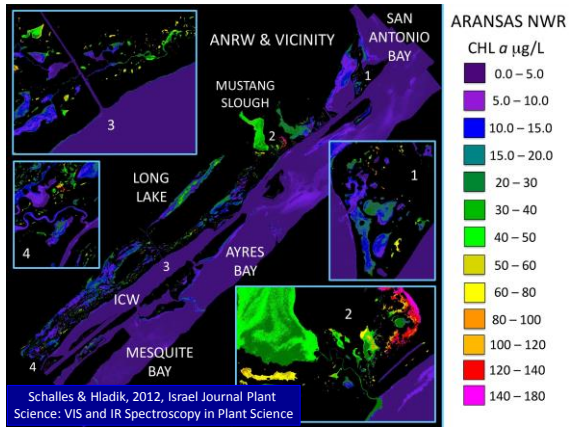
- **Airborne Imaging Campaign at Mission-Aransas NERR in 2008 with CALMIT-University of Nebraska AISA-Eagle Sensor**
- **Mapping products for research and management at MANERR and imagery processing work-flow**
- **Field Survey Methodologies – transect approach used in July, 2008**
- **Delineation of Black Mangrove stands in Redfish Bay, and VARI-green algorithm for estimation of canopy height**
- **Follow-up field survey work in 2011 and detection of significant mangrove freeze damage and gradient of damage**
- **January, 2013 site revisit to evaluate mangrove recovery and above-ground regrowth patterns**
- **Conclusions and next phases of our geospatial work at MANERR, including seasonal WorldView 2 satellite imagery in 2015.**



ECSC PARTNER SCHOOLS JOINED WITH SEVEN NOAA-NERR SITES FOR EIGHT HYPERSPECTRAL IMAGERY ACQUISITIONS WITH THE UNIVERSITY OF NEBRASKA'S AISA EAGLE INSTRUMENT







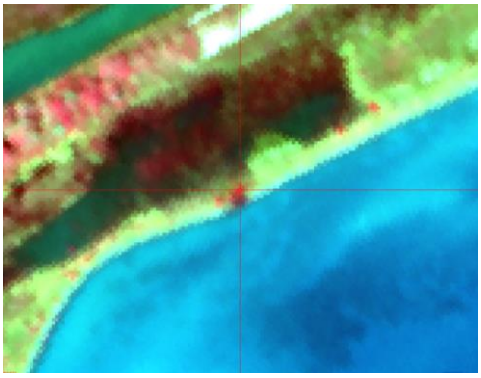
Schalles & Hladik, 2012, Israel Journal Plant Science: VIS and IR Spectroscopy in Plant Science

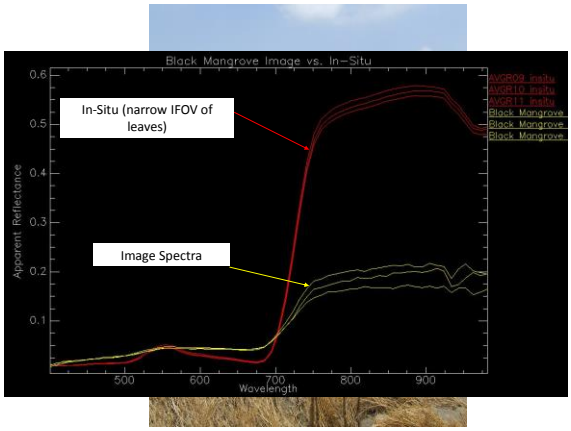
Figures showing GPS point (yellow) and actual location (red). Also the field

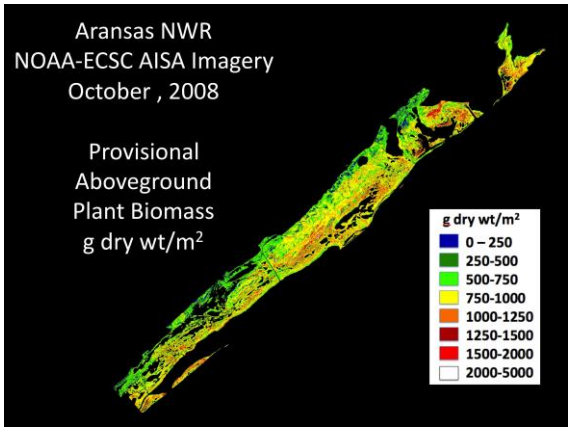
collection of GPS points on a narrow peninsula of land is a natural feature that is useful for testing accuracy.

From: Technical Progress Report on Mission-Aransas National Estuarine Research Reserve AISA+ Image Acquisition and Analysis. Jeffrey S. Vincent, Ph.D., Bureau of Economic Geology, University of Texas at Austin. May, 2009

Black Mangrove (*Avicennia germinans*) Image versus In-Situ Endmembers







Example of flight line imagery, flown as NE / SW diagonals in parallel tracks with ~30% overlap (imagery acquired in late October, 2008)

Imagery Acquisition

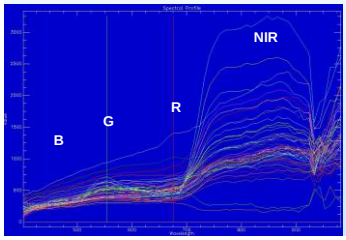
- In October, 2008, 1m hyperspectral images were obtained with an AISA Eagle at MANERR
- These images were then processed using ENVI software
  - Masking: all non-mangrove components were masked out
  - The G_{vari} Vegetation Index was applied to assess plant density/canopy height, using Band Math in ENVI:

    GVI = (Green – Red) / ((Green + Red) – Blue)*
  - Color Density Slicing used to display different size classes

*Gitelson, A.A. et al., 2002. Novel Algorithms for Remote Estimation of Vegetation Fraction. Remote Sensing of Environment 80: 76-87.

Gitelson, Kaufman, Stark, & Rundquist. 2002. Novel algorithms for remote estimation of vegetation fraction. Remote Sensing of the Environment 80: 76-87.

1. NDVI: $(R_{NIR} - R_{red}) / (R_{NIR}+R_{red})$
2. Green VARI: $(R_{green} - R_{red}) / (R_{green} + R_{red} - R_{blue})$
3. NIR / GRN: $(R_{NIR}) / (R_{green} - 1)$



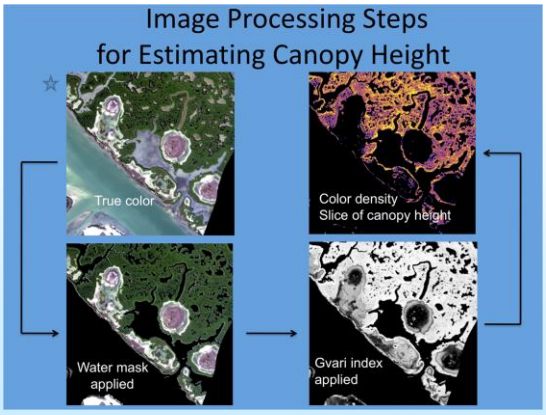
AISA Bands

Blue: 8 (463 nm)

Green: 18 (554 nm)

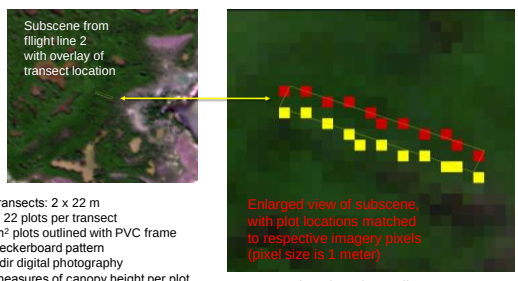
Red: 31 (675 nm)

NIR: 50 (856 nm)



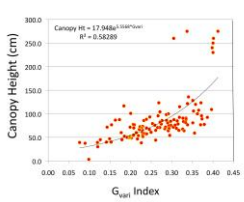
LOCATIONS OF EIGHT MANGROVE SURVEY TRANSECTS IN REDFISH BAY SCIENTIFIC AREA (ALTRICHTER ET JULY, 2008)

Survey transects & AISA imagery



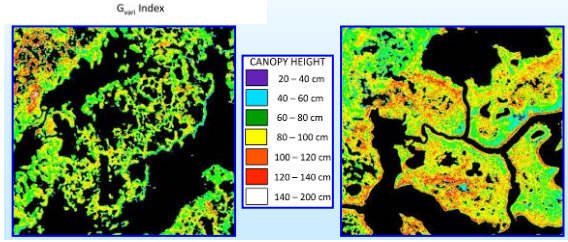
- 8 transects: 2 x 22 m
  22 plots per transect
- 1 m² plots outlined with PVC frame
- Checkerboard pattern
- Nadir digital photography
- 6 measures of canopy height per plot
- Estimations of percent cover by plant species and other habitat conditions

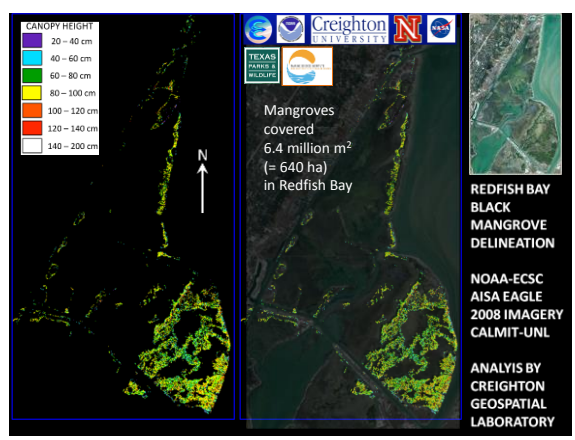
Registration of sampling transect and AISA flight line subscene

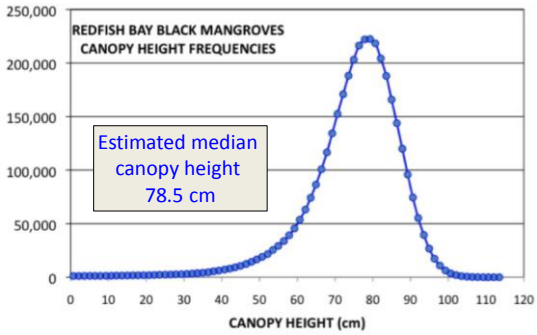


Redfish Bay Subscenes

- Gvari Index was the best predictor of canopy height (R^2 = 0.583)
- Median canopy height for all mangrove pixels was approximately 78.5 cm
- Mangroves were generally taller near larger channels and lagoons (older specimens and/or more favorable for growth?)



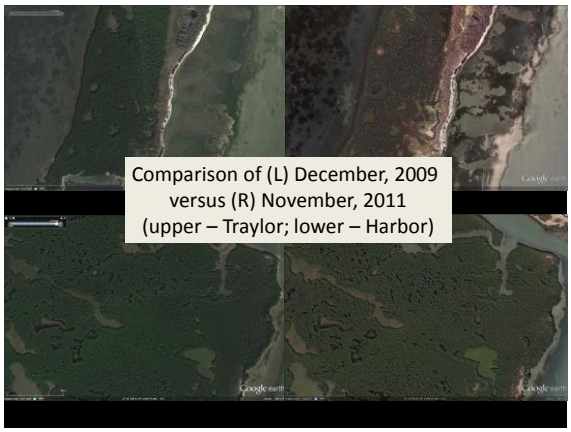




Initial histogram of Black Mangrove canopy height frequency distribution at Redfish Bay. Note: taller trees are not being properly captured in this analysis, but median size appears realistic based on 2008 and subsequent field surveys.

Freeze Damage Encountered in March, 2011

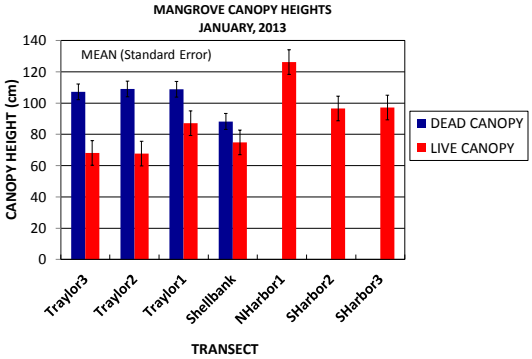
- We discovered extensive areas of mangroves killed by 2 hard freezes in early February, 2011
- A gradient of decreasing damage was documented from north to south in Redfish Bay
- Damage patterns and recovery were analyzed by comparing new high resolution satellite imagery with our 2008 baseline map and transect data

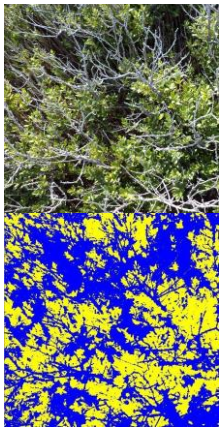


Shellbank Island Site

Intermediate Damage Site at Redfish Bay

First Survey in January, 2013 – Eryn Carpenter



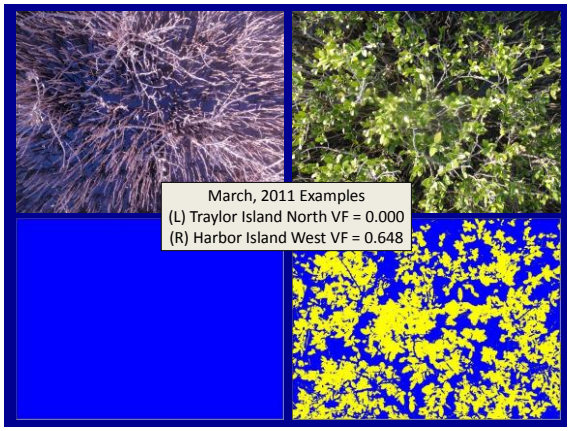


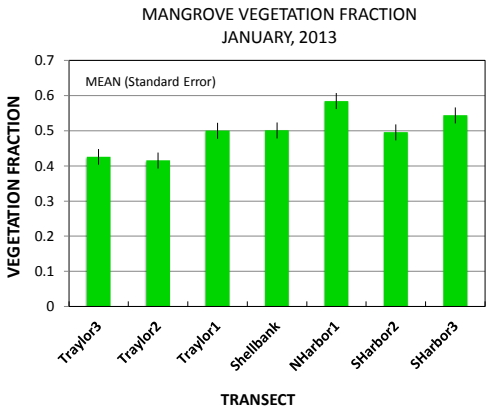
Example of Vegetation Fraction Calculation

1. Load field digital photograph (shown here is frame DSC00069 taken by Eryn Carpenter at Traylor Island North; Transect 1 – Plot 19, Canopy Heights: 85 cm – dead, 57 cm – live) (27° 57' 14.094" N, 97° 4' 24.930" W)

2. Process through "Veg Fraction" custom software (Bryan Leavitt, CALMIT - Univ. of Nebraska) to identify green pixels as fraction of all pixels in the image.

3. In this case, the fraction was 0.450 (45.0% of 262,144 pixels; range across all calculations for 7 transects in January, 2013 was 0.069 – 0.758)





Conclusions and Next Steps

* Most of "suitable" wetland habitat in Redfish Bay is now colonized by Black Mangrove; herbaceous vegetation cover generally less than 5% or non-existent

* Median canopy height of mangroves estimated at 78.5 cm; our technique and VARI-green algorithm is underestimating the rather limited but important occurrence of taller plants (esp above ~ 1.8 m)

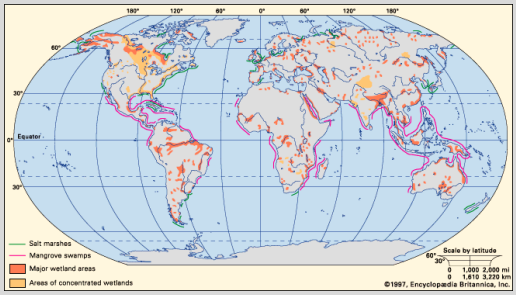
* The Coastal Bend Black Mangroves appear to be quite "hardy", and are recovering rapidly in areas of severe damage in 2011 freeze event

* In 2015, the NOAA-ECSC and MANERR plan to acquire 3 sets of World View 2 imagery in winter, early, and late growing seasons (2 m pixels, 8 bands – very useful for detailed spatial mapping at substantially lower cost than our AISA-Eagle system)

The colonization and age structure of red mangrove (*Rhizophora mangle*) trees along the coast of Texas

Christopher Wilson, Kimberly Jackson and Kenneth Dunton

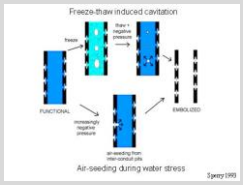
Worldwide Mangrove Distributions

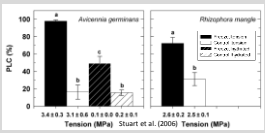


Most recent northern limit described for *Rhizophora mangle* (29° 42.94′ N) by Zomlefer et al. (2006).

Harbor Island, Texas lies at 27° 51.48′ N!

How is this plant boundary enforced?





Stuart et al. (2006)

Frozen Mangrove = Dead Mangrove

Red Mangroves in Texas

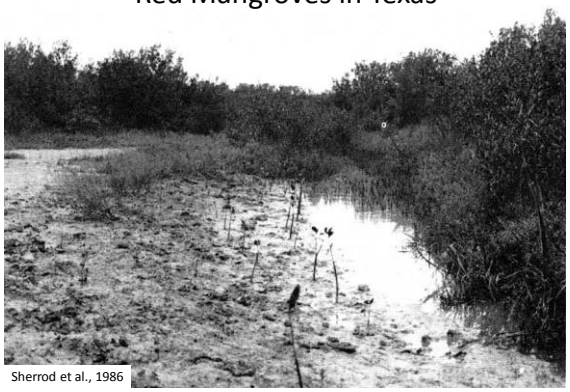
Figure 4.9. Red mangrove (*Rhizophora mangle*) seedlings in "Big Shell Bench" in Padre Island National Seashore, Texas after hurricane Dolly in July 2008. Photo by Jace W. Tunnell (08.02.08).

Figure 4.10. Red mangrove in Harbor Island, Texas (July 2006).

Continuous account in Texas since 1980's:

- Sherrod et al. 1986*
- Tunnell 2002
- Montagna et al. 2007
- Montagna et al. 2011 (Pictures)

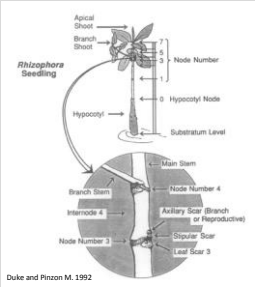
Red Mangroves in Texas



Sherrod et al., 1986

Methods: Survey Location

Methods: Aging Mangroves



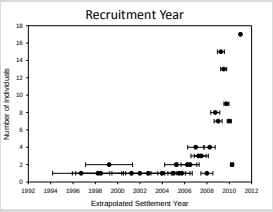
Calculating Node Production Rate

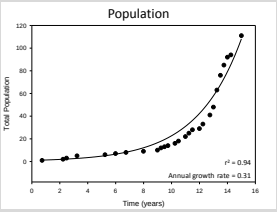
"Plant and Wait"

- 4 propagules were planted in UTMSI WEC
- Plantings included sun and shade plots
- After two years, the total node number was quantified for each plant
- The node production rate (*4.08 ± 0.74 nodes year* $^{-1}$) was used to extrapolate tree age

** Error becomes larger as you extrapolate further in time*

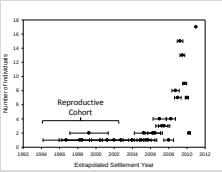
Survey Results: Demographics

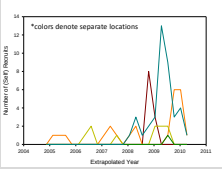




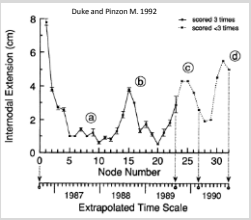
**Mean node production = 4.08 ± 0.74 nodes year* $^{-1}$ *(n = 4)*

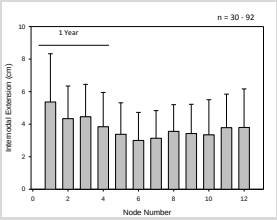
Why the recent plant explosion?





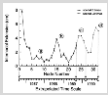
Mangrove Growth: Juvenile Reserves

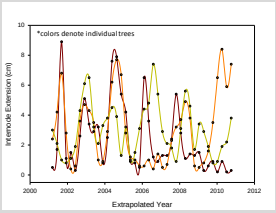


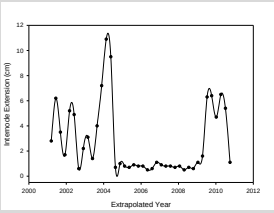


Reserves likely supplement plant growth during initial year of establishment

Mangrove Growth: Annual Patterns

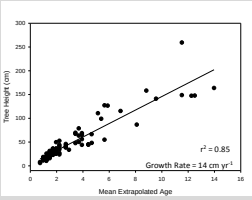






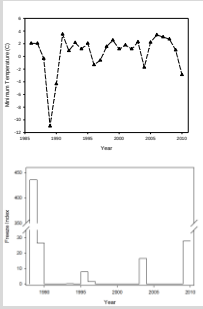
Although mangroves exhibit indeterminate growth, red mangroves in TX have a pronounced annual signal that is subject to perturbation.

Mangrove Growth: Rate and Maximum



Red mangroves typically achieve site-specific maximum canopy heights (TX < 3m).

How cold is too cold?



Freeze index= -Σ [Freezing Temperature (°C)] x [Duration of Temperature (hours)]

Infrequent freezing temperatures are likely limiting the maximum canopy height of red mangroves.

New Hypothesis Alert : Black mangrove trees facilitate the expansion of red mangrove trees through insulation.

Documented Mangrove Facilitation

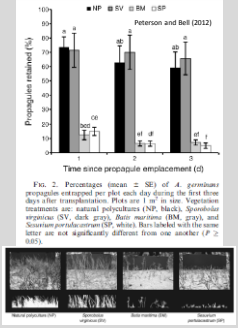
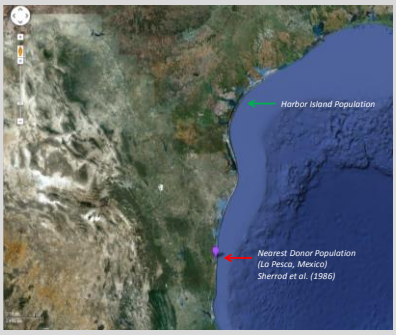


FIG. 2. Percentages (mean ± SE) of *A. germinans* propagules entrapped per plot each day during the first three days after transplantation. Plots are 1 m^2 in size. Vegetation treatments are: natural polycultures (NP, black), *Spartinalar virginicus* (SV, dark gray), *Batis maritima* (BM, gray), and *Sesuvium portulacastrum* (SP, white). Bars labeled with the same letter are not significantly different from one another ($P \geq 0.05$).

How did *R. mangle* get here?



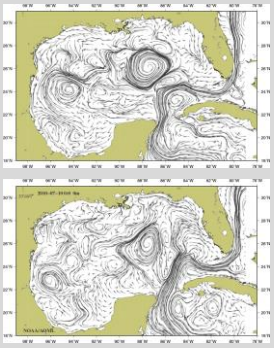
How did *R. mangle* get here?

→ Propagules are positively buoyant

→ Prevailing SW winds in spring and summer

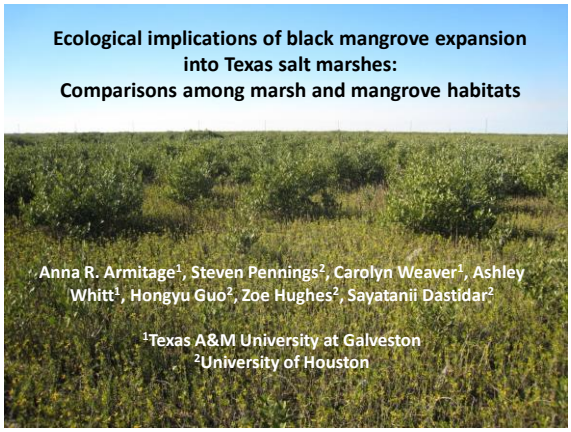
→ Numerous eddies spinning off of loop current

→ Harbor Island is easy target



Future Directions in Research

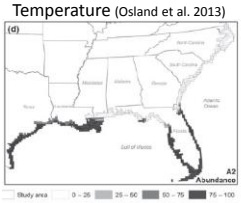
1. Persistence and Reproduction
   a. How cold is too cold?
   b. Quality and quantity of propagules
2. Trajectory of population
   a. Carrying capacity TBD
   b. Reproduction vs. immigration
   c. Potential to *serve* as a source population
3. Nutrient Cycling
   a. No soil aeration!
   b. OM likely different
4. Fauna
   a. Canopy
   b. intertidal structure



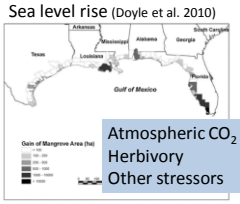
Marsh → Mangrove

- Gulf of Mexico coastal wetlands are transitional between marshes and mangroves
- Mangrove expansion rate may be accelerating

Temperature (Osland et al. 2013)



Sea level rise (Doyle et al. 2010)

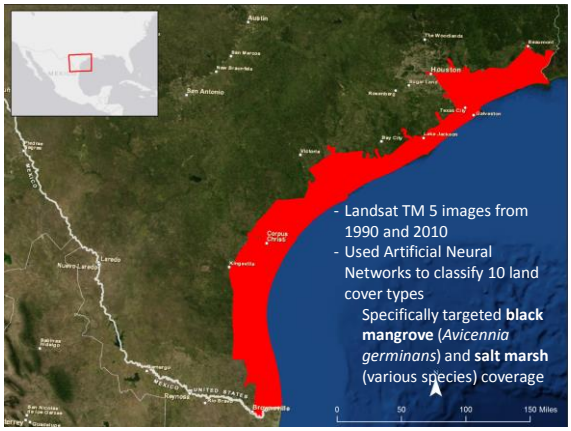


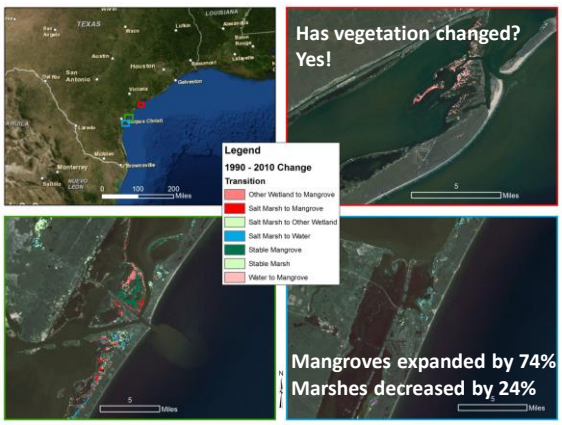
Atmospheric CO_2
Herbivory
Other stressors

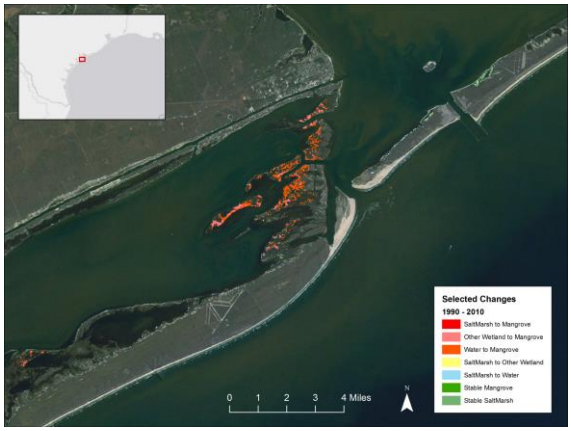
Habitat change in Texas: One perspective

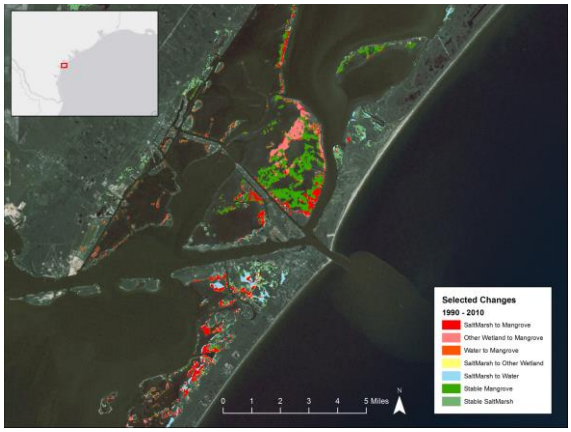
- Has vegetation composition in Texas coastal wetlands changed?
  - Where?
  - By how much?
  - On what time scale?

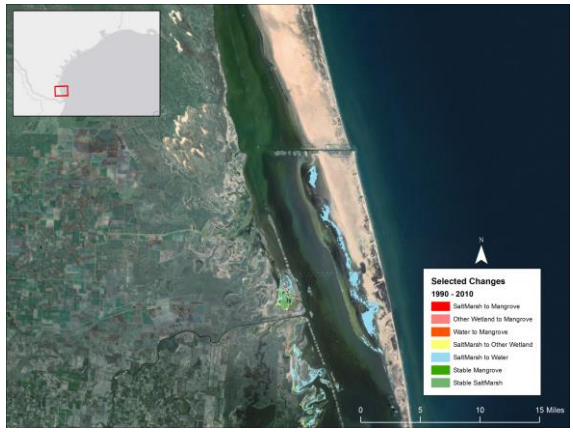
→ One perspective: Use of remote sensing to identify "hot spots" of expansion over the last 20 years (courtesy W. Highfield, TAMUG)











Mangrove increase

- **Mangroves increased by 74%**
  - 16 km^2 increase
- Mostly conversion from:
  - Upland pasture – indicates upland migration of salt marsh?
  - Salt marsh
  - Other wetland
  - Water – probably salt marsh at low tide in 1990

  →**Mangrove expansion occurred in areas of marsh or upland**

Marsh decrease

- **Salt marshes decreased by 24%**
  - 77.8 km^2 decrease
- Mostly converted to:
  - Upland pasture
  - Water – submergence
  - Other wetland
  - Bare

  →**Only 7.7% of the salt marsh loss was due to mangrove expansion**

  →**Mangrove area small relative to marshes**

  →**Marsh loss largely due to habitat loss**

Questions

→ Mangroves are increasing, marshes are decreasing

- What are the species- and process-level implications of these vegetation shifts?
- Are there ecological differences between marsh and mangrove habitats?
  1. Comparisons among stands of marshes and mangroves
  2. Experimental mangrove removal/marsh revegetation

Approach

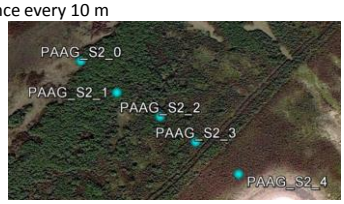
- Study sites in "hot spot" of expansion, Port Aransas vicinity
  - 3 marsh
  - 4 mangrove-dominated (mix)

→Advantage: Communities established

→Disadvantage: Spatial separation

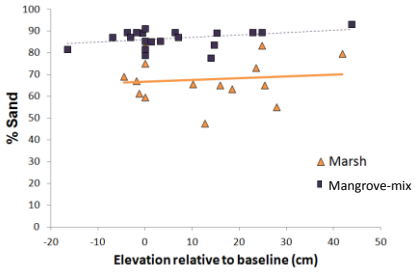
Approach

- Transects along elevation gradient perpendicular to shoreline
  - Used relative elevation as a covariate
  - Marshes had slightly higher elevation at upper end
- Sampled edaphic, vegetation, and nekton characters in Sept. 2012
  - 5 evenly spaced stations:
    - Soil: moisture, salinity, CNP, pH, mV
  - Plant presence/absence every 10 m
  - Nekton in seine nets at water's edge
    - Pit traps
    - Light traps



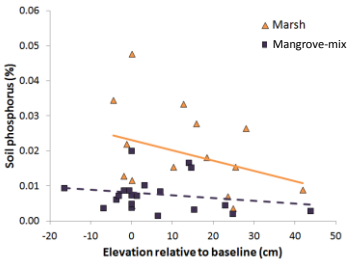
Edaphic characteristics: grain size

- Mangrove sites sandier
  → Located on barrier island
- No elevation change



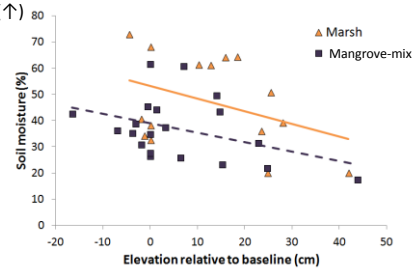
Edaphic characteristics: sediment CNP

- Soil P higher in marsh sites
  - No significant elevation pattern
- C and N higher in marsh sites, but not significantly
- Nutrient availability may be linked to sediment and/or vegetation type
- Nitrogen competition between *Avicennia* and *Spartina* (McKee & Rooth 2008)
  - P competition?
  - Analyses of leaf tissue ongoing
  - Concurrent enrichment experiments



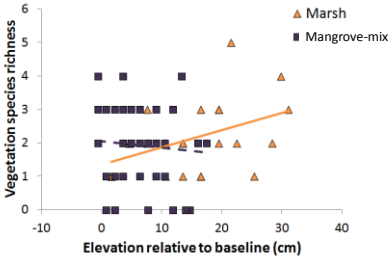
Edaphic characteristics: elevation gradient

- Soil moisture decreased at higher elevations
  - No vegetation type effect
- Other soil characters that varied only with elevation:
  - Soil salinity (↑)
  - Redox (↑)
  - pH not affected by elevation or vegetation type



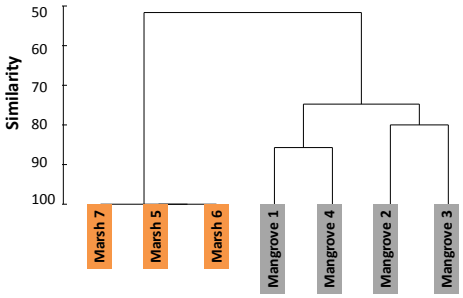
Vegetation characteristics: Richness

- Species richness similar
  →No habitat type effect
  →No elevation gradient



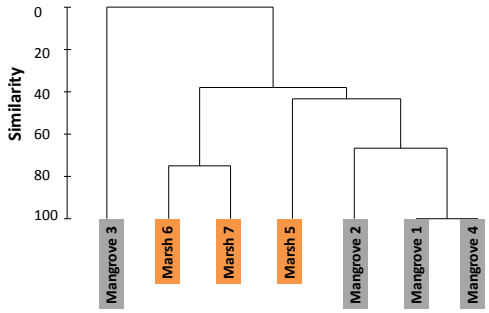
Vegetation characteristics: Composition Low elevation

- Species composition distinct at low elevation



Vegetation characteristics: Composition High elevation

- Species composition heterogeneous at high elevation



Nekton composition

→ Abundance and richness similar

→ Composition different… …May be linked to seagrass density

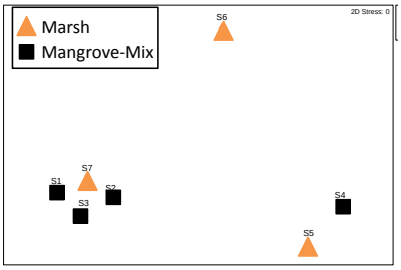
Nekton characteristics

→Community composition not linked to vegetation type

→Further suggests links to seagrass density

What does vegetation type mean for food webs?

Isotope analyses are ongoing



Summary

- Edaphic characteristics:
  - Few differences definitively linked to vegetation type
  - Some elevation patterns
- Vegetation:
  - Richness similar, composition different , especially at low elevation
  - Ongoing studies: Linked to processes such as accretion, nutrient storage?
- Nekton:
  - Richness and abundance similar, composition different
  - Linked to seagrass?
  - Ongoing studies: trophic relationships

Next steps

- Still many questions left to be answered!
  - →More sites, wider spatial array
  - →Seasonal measurements: plant and fishery productivity
  - →More process- and ecosystem-level measurements
  - →Integrate with experimental approach

Acknowledgements

Funded by Texas Sea Grant (NOAA)

Sea Grant Texas AT TEXAS A&M UNIVERSITY TexasSeaGrant.org

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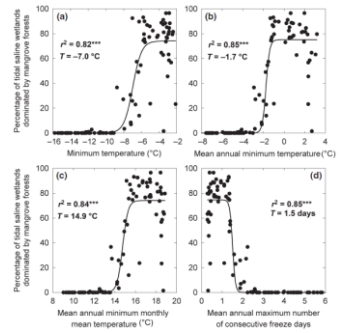
Ecological implications of black mangrove expansion into Texas salt marshes:
Insights from a large-scale mangrove removal experiment

Steven Pennings, Hongyu Guo, Anna Armitage, Zoe Hughes, Carolyn Weaver, Sayatani Dastidar

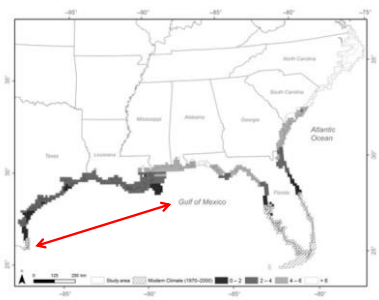
University of Houston
Texas A&M University, Galveston

Thank You Texas Sea Grant!

Mangroves are expanding



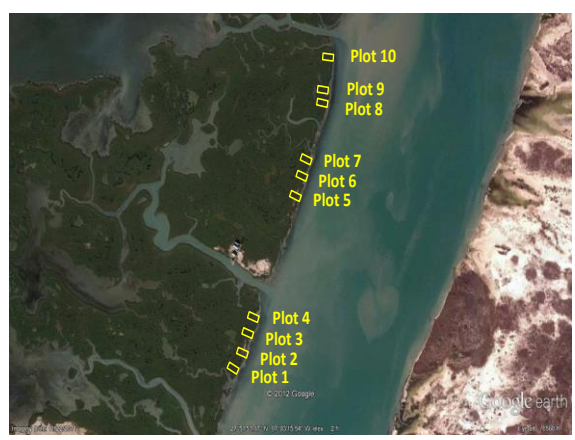
Osland et al. 2013 GCB

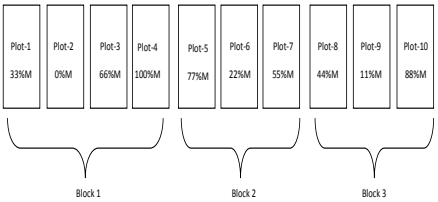


Osland et al. 2013 GCB

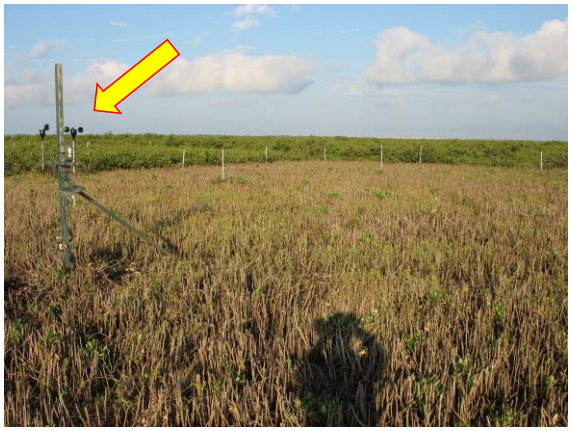
Natural versus manipulative experiments

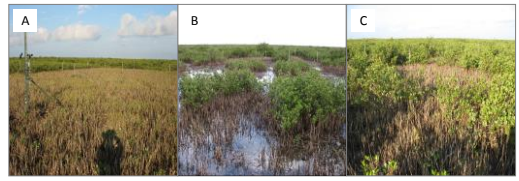
- Natural-large spatial and temporal scale
- Experimental-better control of confounding variables



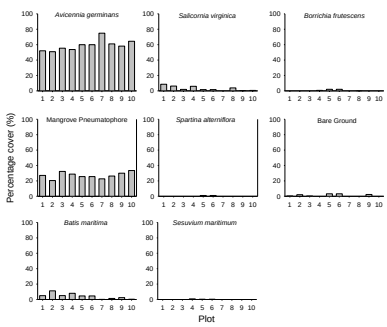


Layout of the 24 x 42 m experimental plots on Harbor Island in Port Aransas. Cleared over summer of 2012. M: mangrove cover

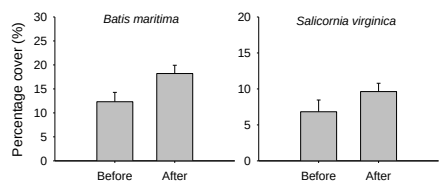




Selected experimental plots after mangrove clearing. A: Plot 2 (0% mangrove cover); B: Plot 9 (11% mangrove cover) C: Plot 8 (44% mangrove cover).



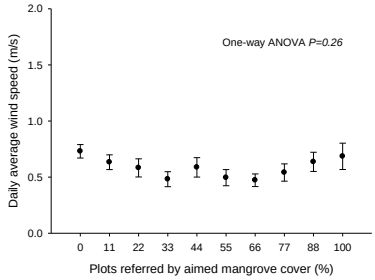
Plant percentage cover (by species) in the experimental plots **before** the mangrove clearing. Data shown are averages of the 84 1×1m quadrats in each plot



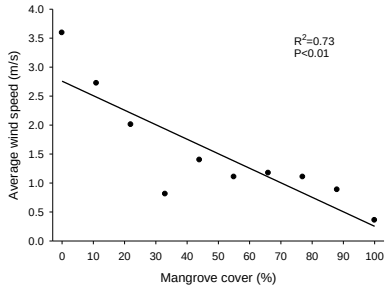
Changes in percentage cover for *Batis maritima* and *Salicornia virginica* before (in May 2012) and after (in November 2012) mangrove tree clearing in plot 2 (0% mangrove cover plot; cleared in July 2012). Data are means + SE.

Before (2012) data for
- soil water content
- porewater salinity
- organic content

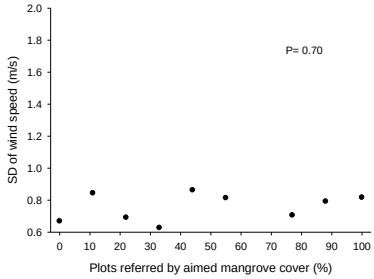
After data to be collected summer 2013



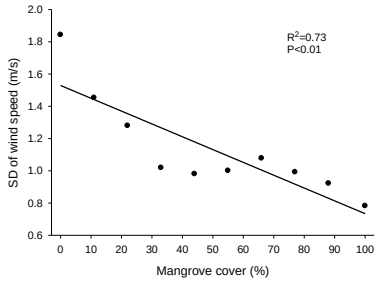
Daily average wind speed across plots **before** mangrove tree clearing (June 5-July5, 2012). Data are means ±SE. Analyses only included wind data with wind directions from channel into each plots.



Average wind speed across plots **after** mangrove tree clearing (September 10-November 10, 2012). Analyses only included wind data with wind directions from channel into each plots.



Standard deviation (SD) of wind speed across plots **before** mangrove tree clearing (June 5-July 5, 2012). Analyses only included wind data with wind directions from channel into each plots.



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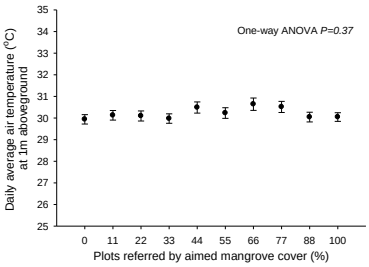
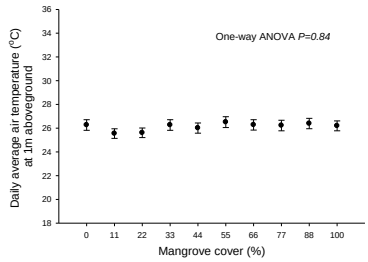


Daily average air temperature at 1m aboveground across plots **before** mangrove tree clearing (June 5-July5, 2012). Data are means ±SE.



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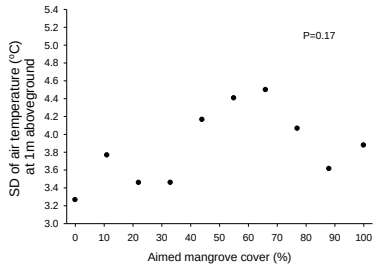

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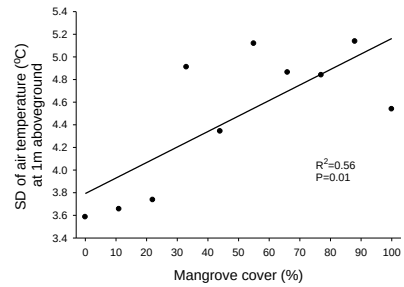

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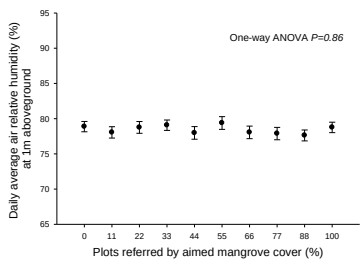
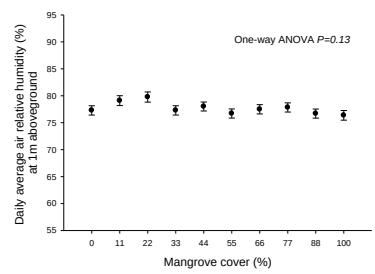
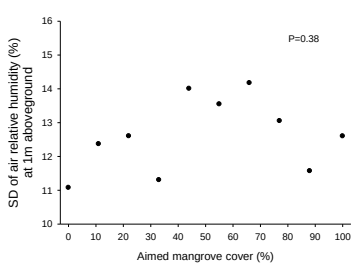


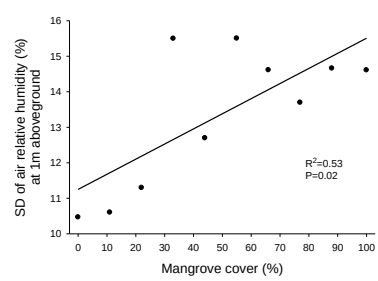
Daily average air relative humidity at 1m aboveground across plots **before** mangrove tree clearing (June 5-July5, 2012). Data are means ±SE.



Daily average air relative humidity at 1m aboveground across plots **after** mangrove tree clearing (September 10-November 10, 2012). Data are means ±SE.



Standard deviation (SD) of air relative humidity at 1m aboveground across plots **before** mangrove tree clearing (June 5-July 5, 2012).



Standard deviation (SD) of air relative humidity at 1m aboveground across plots **after** mangrove tree clearing (September 10-November 10, 2012).

Conclusions (so far)

Marsh vegetation increasing where mangroves removed

Mangrove density has strong effects on microclimate at 1m.
- Reduces wind
- Reduces wind SD
- Increases temperature SD
- Increases humidity SD

Appears to be a threshold between 22 and 33 percent cover

Not much happening with soil temperature so far.

We hypothesize that effects on temperature and humidity may vary seasonally.

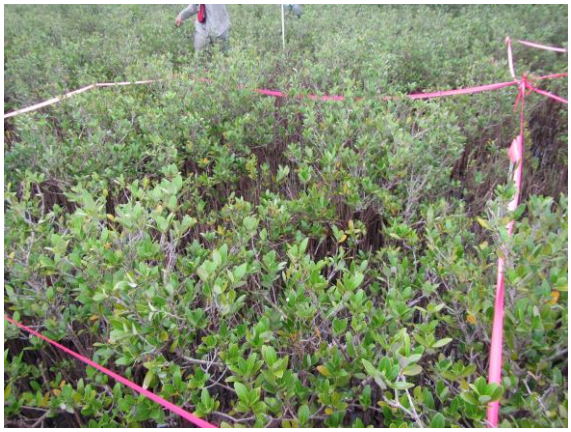
Future work

Next 2 years
Continue plant and climate measurements

Next 3-5 years:
Soil salinity
Wave environment
Vegetation
Arthropods
Benthic macrofauna
Nekton
Birds

Long-term:
Soils
Carbon cycle
Soil infauna

Collaborators welcome!



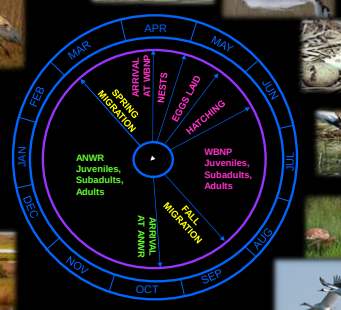
"Habitat Replacement by Mangrove Establishment: Implications for Whooping Crane use"

Elizabeth H Smith, PhD
Whooping Crane Conservation Biologist
Nicole A. Davis, M.S.
Ph.D. Graduate Research Assistant

INTERNATIONAL CRANE FOUNDATION

THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

W ing C cle



Whooping Crane Ecological Requirements in Wintering Range

Primary Food Items

- Blue Crab
- Wolfberry Fruits
- Clams, Snails, Shrimp
- Acorns, Snakes, Lizards, Insects, Small Rodents

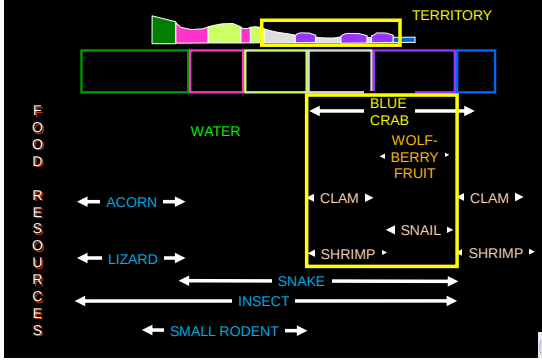
Aransas National Wildlife Refuge
Blackjack Peninsula

Coastal Habitat Availability

Elevation: 0-9 ft
Tidal Range: 1-2 ft

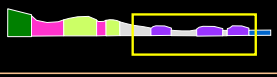
Oak Woodland | Fresh Marsh | Coastal Prairie | Shallow Flat | Coastal Marsh | Bay

HABITATS



Land Use/Land Cover

Oak Woodland | Fresh Marsh | Coastal Prairie | Shallow Flat | Coastal Marsh | Bay



LEGEND
- Woodlands
- Fresh Marsh
- Coastal Prairie
- Shallow Flat
- Coastal Marsh
- Bay

Employing the Conservation Design Approach on Sea-Level Rise Impacts on Coastal Avian Habitats along the Central Texas Coast

Funded by the Landscape Conservation Cooperative

International Crane Foundation

Gulf Coast Bird Observatory

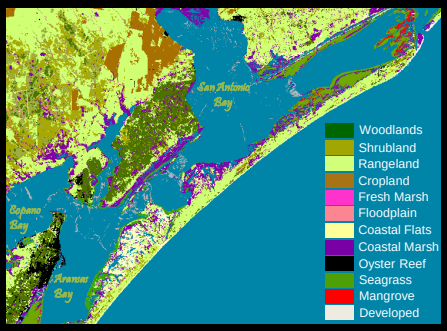
Harte Research Institute for Gulf of Mexico Studies – TAMU-CC

Conrad Blucher Institute – TAMU-CC

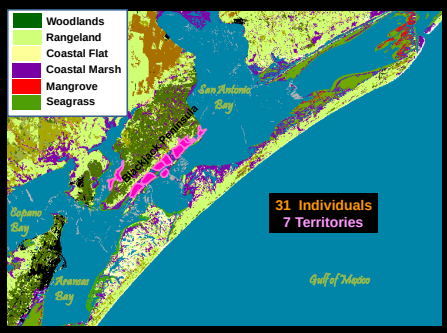
The Nature Conservancy of Texas

Mission-Aransas National Estuarine Research Reserve – UTMSI

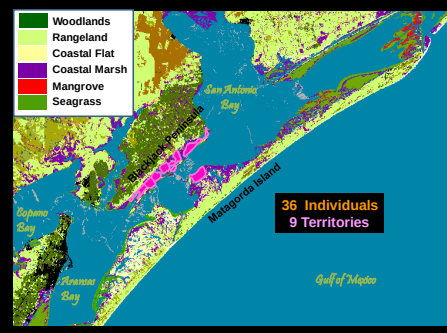
LAND USE/LAND COVER MAP



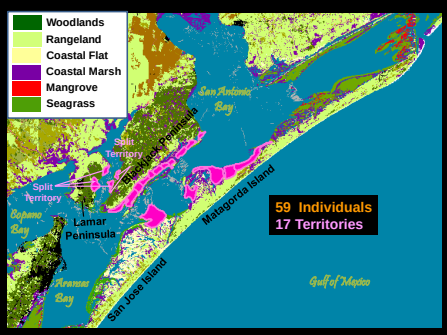
Whooping Crane Territories 1950



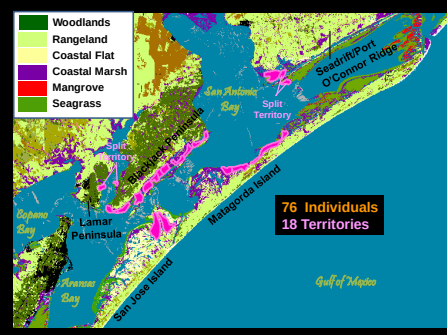
Whooping Crane Territories 1961



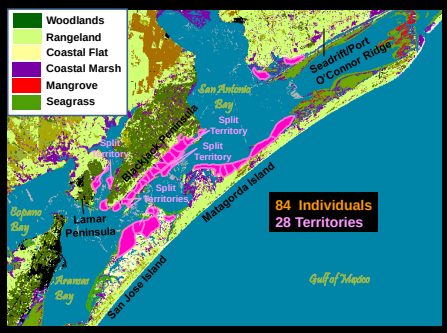
Whooping Crane Territories 1971



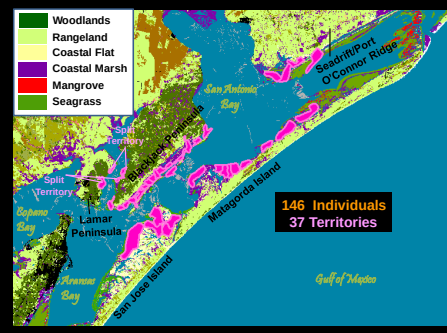
Whooping Crane Territories 1979



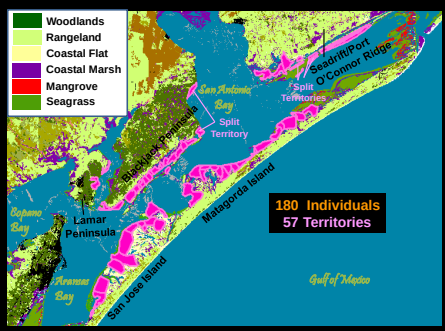
Whooping Crane Territories 1985



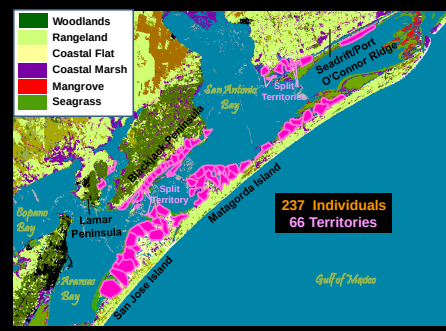
Whooping Crane Territories 1990



Whooping Crane Territories 2000



Whooping Crane Territories 2006



Mangrove Establishment

- Indicator species: sensitive to environmental changes
- Increasing temperature
- Decreasing freeze event frequency
- Decreasing dissolved oxygen in water
- Sensitive to sea-level changes

Montagna et al. 2011 Coastal Impacts *in* The Impact of Global Warming on Texas

Mangrove Establishment

- Habitat conversion from marsh to mangrove reduces habitat availability
- Whooping cranes cannot walk through mangroves to forage
- Predators may have an advantage within mangrove/upland areas

What ICF is Doing

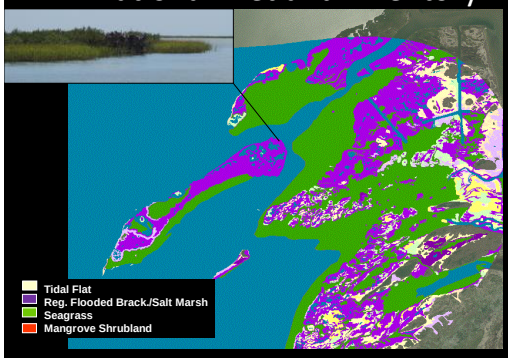
- Provide support letters for mangrove research
- Assist in mapping current mangrove establishment in whooping crane winter territory
- Assess mangrove habitat use by whooping cranes
- Predict future mangrove expansion

TOP 2008 Natural Color

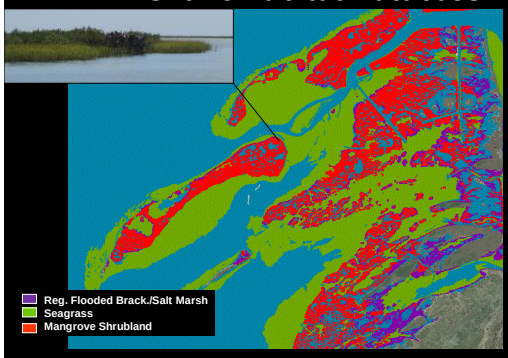
TOP 2008 Color Infrared

Tx Ecological Systems Database

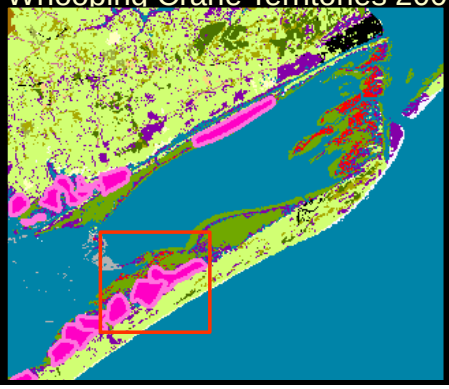
National Wetland Inventory



Tx Benthic Habitat Database



Whooping Crane Territories 2006

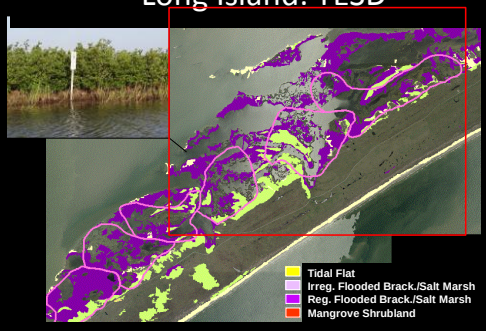


Long Island: 2006 Territories

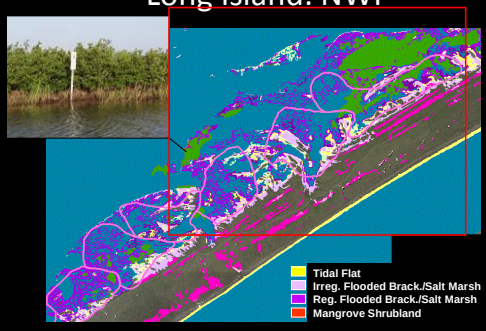
Long Island: 2001-2010 Pts

Long Island: 2006 Territories

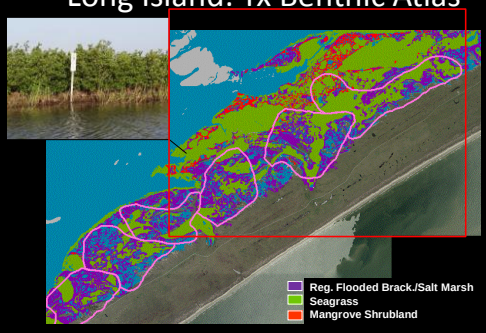
Long Island: TESD



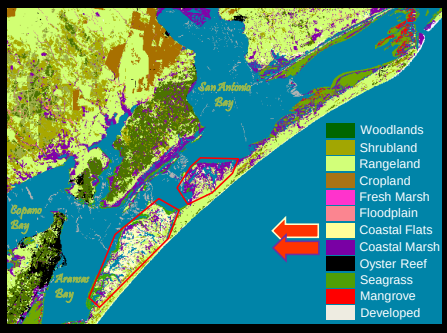
Long Island: NWI



Long Island: Tx Benthic Atlas



LAND USE/LAND COVER MAP



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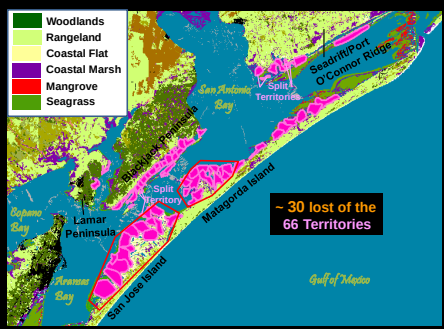
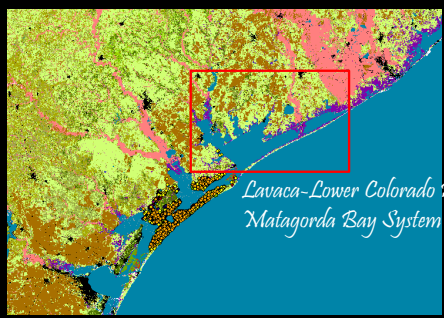


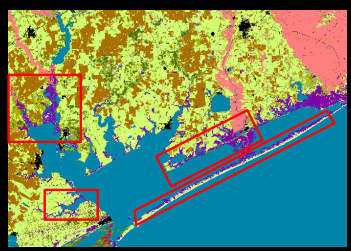
Whooping Crane Recovery Goals
(Downlist Criteria)

- 1000 individuals
- 250 nesting pairs
- 10 years

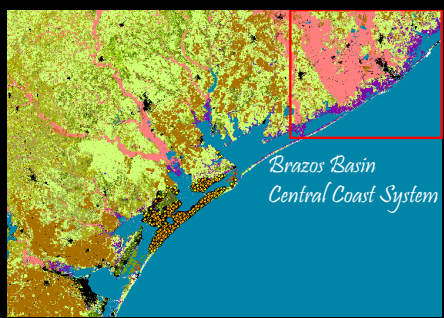
- 250 winter territories @ 500 ac each = 125,000 ac

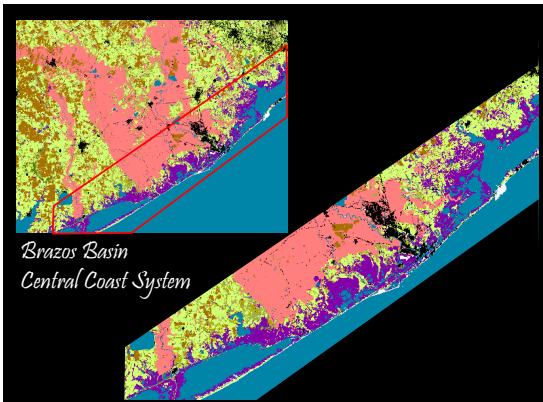
Future Whooping Crane Expansion

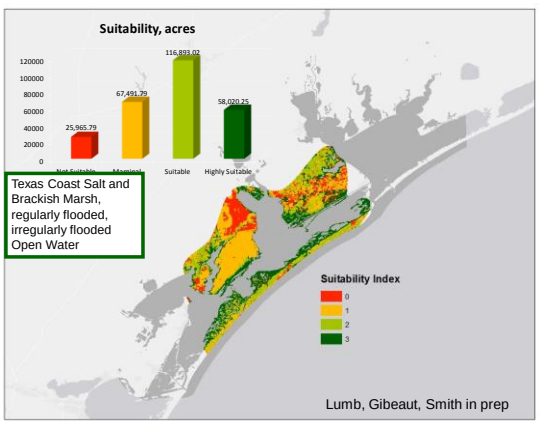


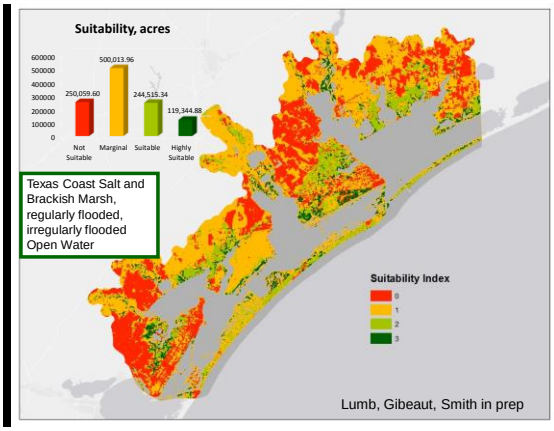


Future Whooping Crane Expansion









Conservation Questions

- Does habitat conversion = essential habitat lost?
- Is loss primarily related to habitat structure changes?
- Are primary food resources impacted?
- How will sea level rise affect habitat type and extent?
- Where will Whooping Crane expansion occur?

Effects of plants as

- Sediments modifiers
  - light, temperature, chemistry regulators of benthic habitats
- Food source
  - Fresh and detrital organic matter
- Structural support
  - Nursery habitat, coastal stabilization, run-off filtration

Literature Summary by (Alfaro 2010)

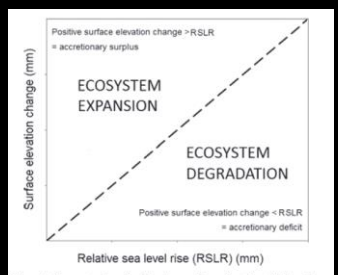


Fig. 4. Conceptual classification of wetland stability by accretionary status. SLR, sea level rise. Modified from Stevenson *et al.* (1986).

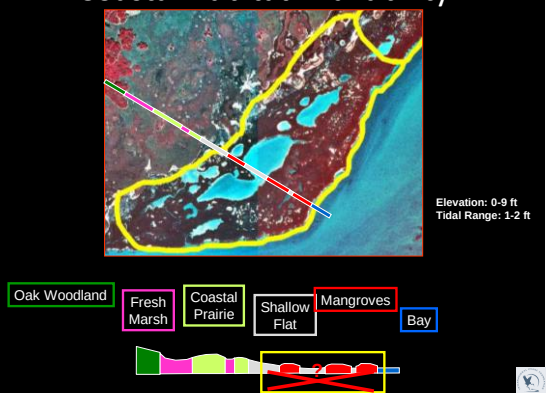
Friess et al. 2011

Habitat Conversion Trend

- Flats > Marshes
- Marshes > Mangroves
- Upland > Marsh/Mangrove?

- Drivers
  - Relative sea level rise
  - Lack of sediment supply
  - Temperature shifts
  - Freshwater inflows

Coastal Habitat Availability



Temporal-Spatial Scales

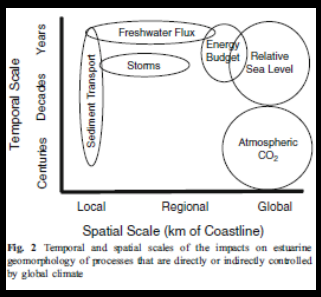


Fig. 2 Temporal and spatial scales of the impacts on estuarine geomorphology of processes that are directly or indirectly controlled by global climate

Day et al. 2008

Next Steps

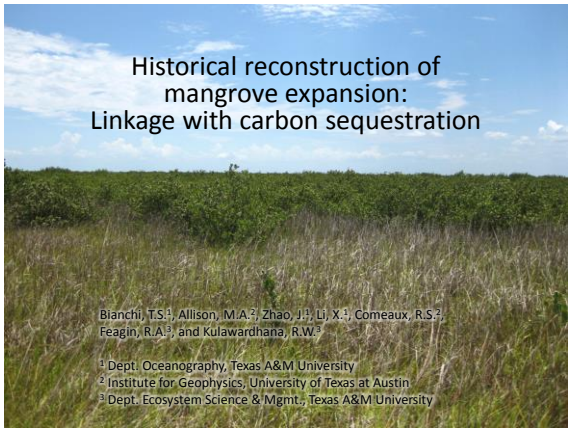
- Comprehensive mapping project (multispectral, extensive groundtruthing)
- Understand mangrove establishment, ecology, expansion rates
- Evaluate use of mangrove habitats by Whooping Cranes, preferred prey items, potential predators
- Predict how climate change will affect habitat availability for conservation prioritization

Thank You!

PLEASE CONTACT:
Liz Smith, Whooping Crane Conservation Biologist
International Crane Foundation
Texas Office, 361-543-0303

Liz Smith, Whooping Crane Conservation Biologist
International Crane Foundation
Texas Office, 361-543-0303

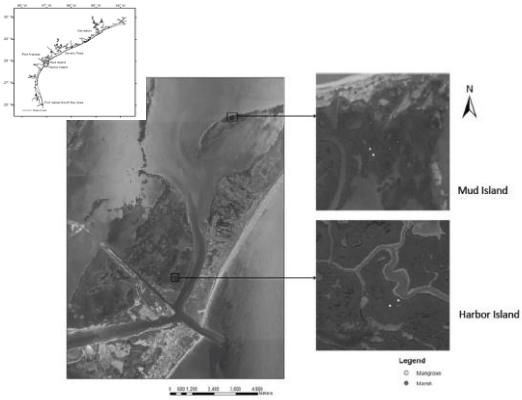
This presentation dedicated to Dave Smith

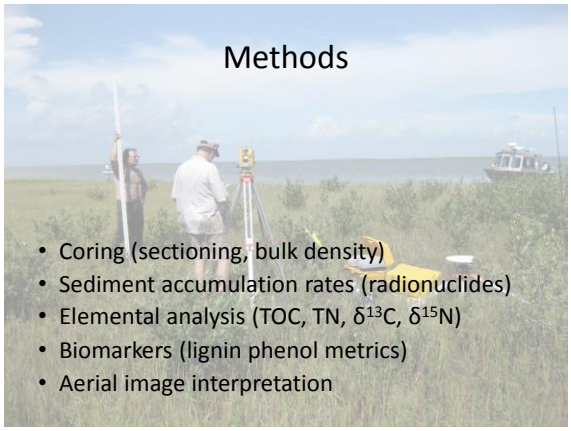


Questions

1. Can we determine when mangroves historically colonized a site?

2. Is there a difference in the carbon sequestration rate between *A. germinans* and *S. alterniflora*, at a common site?





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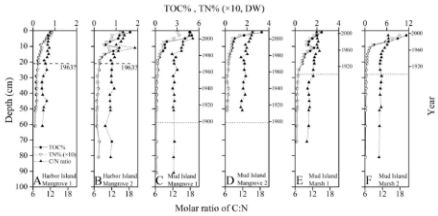
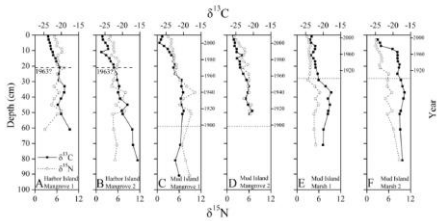
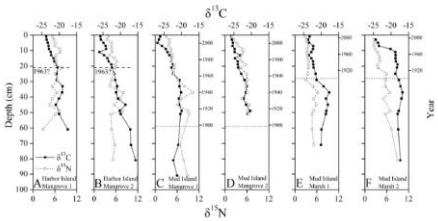


C3 plants (like woody mangroves) = -35 to -20 (-28 = *A. germinans*)
C4 plants (like herbaceous marsh) = -19 to -9 (-13 = *S. alterniflora*)

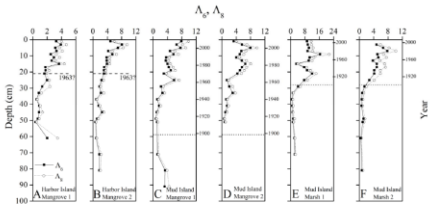


C3 plants (like woody mangroves) = -35 to -20 (-28 = *A. germinans*)
C4 plants (like herbaceous marsh) = -19 to -9 (-13 = *S. alterniflora*)

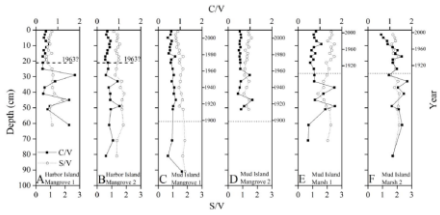
Marsh benthic algae = -16 to -27.7
Coastal phytoplankton = -18 to -24



Lignin phenols (per 100 mg OC)
Λ_G = vanillyl + syringyl phenols
Λ_S = vanillyl + syringyl + cinnamyl phenols

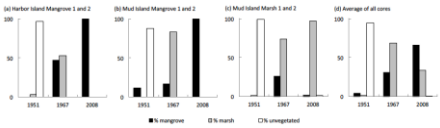


Plant sources of lignin
C/V= cinnamyl/vanillyl
S/V = syringyl/vanillyl

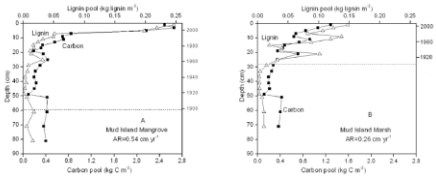


- The most obvious differences in TOC are between the two sites
- For biomarkers and isotopic composition, there are no big differences between mangroves and marsh core locations

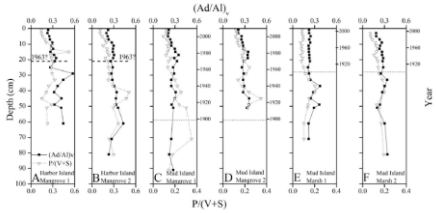
- TOC and C:N ratio increased around 1960s
- Biomarkers also record changes around 1960s
- Aerial images show changes around 1960s



2. Is there a difference in the carbon sequestration rate between *A. germinans* and *S. alterniflora*, at a common site?



Indices of lignin decay
Ad/Al = vanillic acid:vanillin
P/(V+S) = p-hydroxyl/(vanillyl+syringyl)



Station	Annual sediment accretion (cm y^{-1})	Annual sediment accumulation (tonnes ha^{-1} yr^{-1})	Carbon sequestration rate (g $C m^{-2} yr^{-1}$)	Lignin storage rate (g lignin m^{-2} yr^{-1})
Mud Island (Mangrove 1 and 2)	0.74 ± 0.21 (^{137}Cs-1963)	49 ± 19 (^{137}Cs-1963)	270 ± 12 (^{137}Cs-1963)	20.3 ± 0.2 (^{137}Cs-1963)
	0.54 ± 0.15 (^{210}Pb)	35 ± 14 (^{210}Pb)	233 ± 11 (^{210}Pb-1963)	19.4 ± 0.6 (^{210}Pb-1963)
Mud Island (Marsh 1 and 2)	0.18 ± 0.06 (^{137}Cs-1963)	12 ± 6 (^{137}Cs-1963)	101 ± 23 (^{137}Cs-1963)	12.7 ± 3.9 (^{137}Cs-1963)
	0.26 ± 0.04 (^{210}Pb)	17 ± 4 (^{210}Pb)	125 ± 11 (^{210}Pb-1963)	16.5 ± 1.3 (^{210}Pb-1963)

Conclusions

- Both sites converted from unvegetated flats (likely some algal cover) to vegetated wetland in the 1960s
- Biomarkers and mobile materials likely represent the 'regional' vegetation dynamics, rather than what is under a particular plant
- Lignin deposition (wood) and accretion rate increase under *A. germinans* plants (compared to *S. alterniflora*). Lignin carbon pool is stable, compared with other TOC components.
- Carbon sequestration rate is likely higher under *A. germinans* vs. *S. alterniflora*, over the long-term