An Update on Environmental Applications:
Data driven technology to support planning and operations

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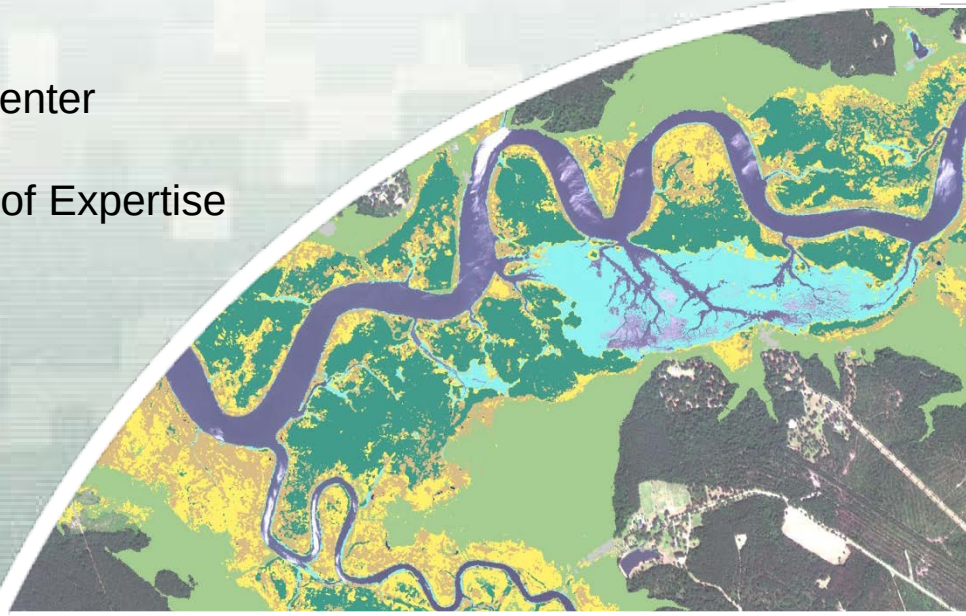
Mobile, AL



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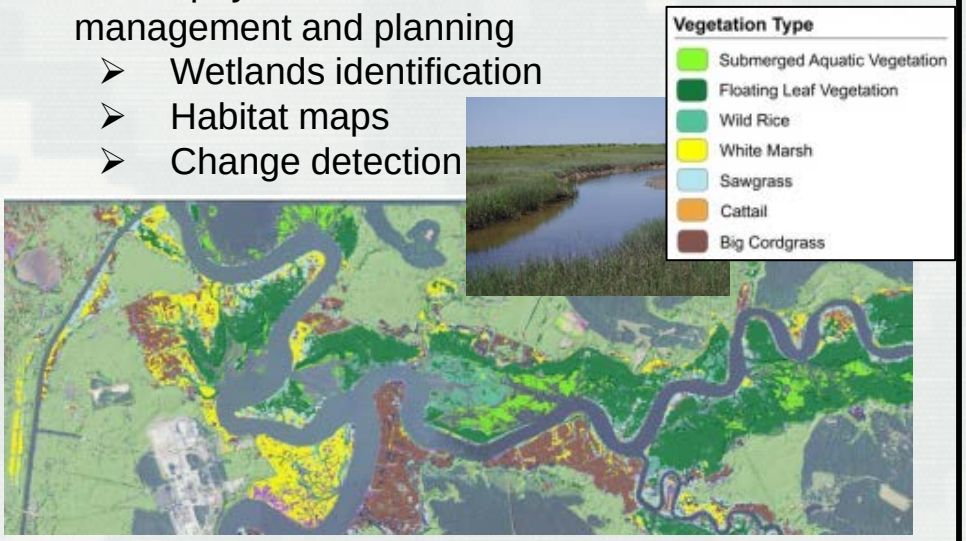
Environmental Applications

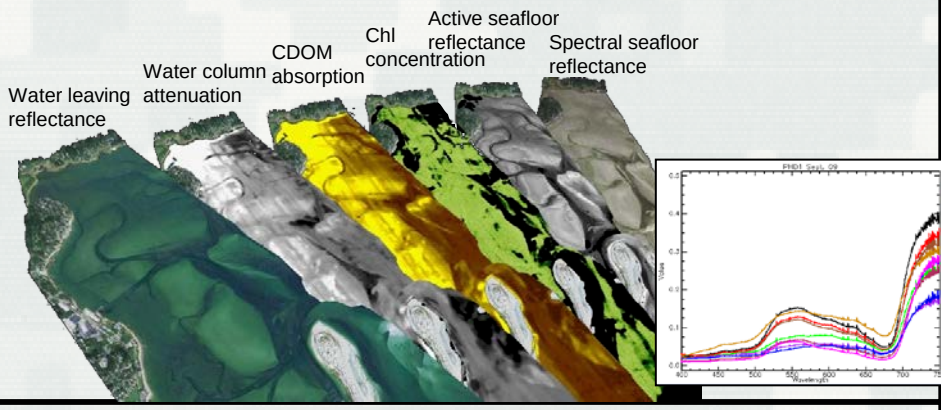
Land Cover and Habitat Characterization – identify critical physical and natural features for resource management and planning

- Wetlands identification
- Habitat maps
- Change detection



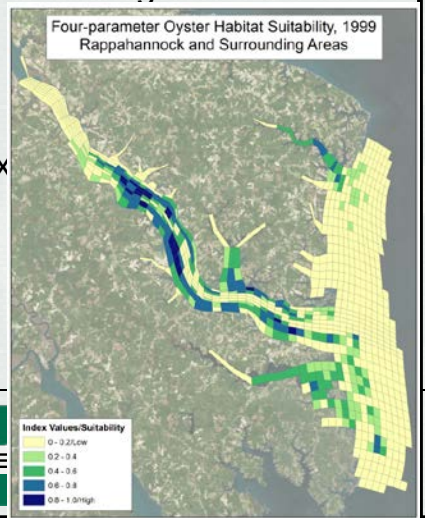
Benthic Habitat/Water Quality Mapping – identify habitats such as submerged aquatic vegetation and water quality indicators

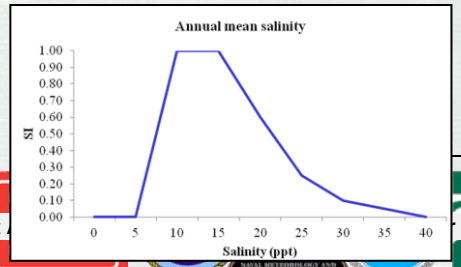
- Operations support
- Restoration/mitigation planning



Critical Species Detection & Modeling – discriminate particular species and habitat suitability for ecosystem restoration and monitoring

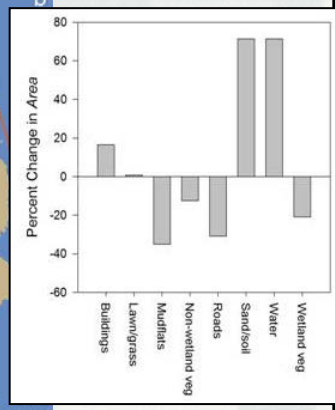
- Invasive/threatened/ endangered species identification
- Habitat suitability index analysis





Landscape Modeling – link landscapes to ecological processes to better predict ecosystem changes

- Landscape structure analysis
- Ecosystem restoration planning



R&D Focus

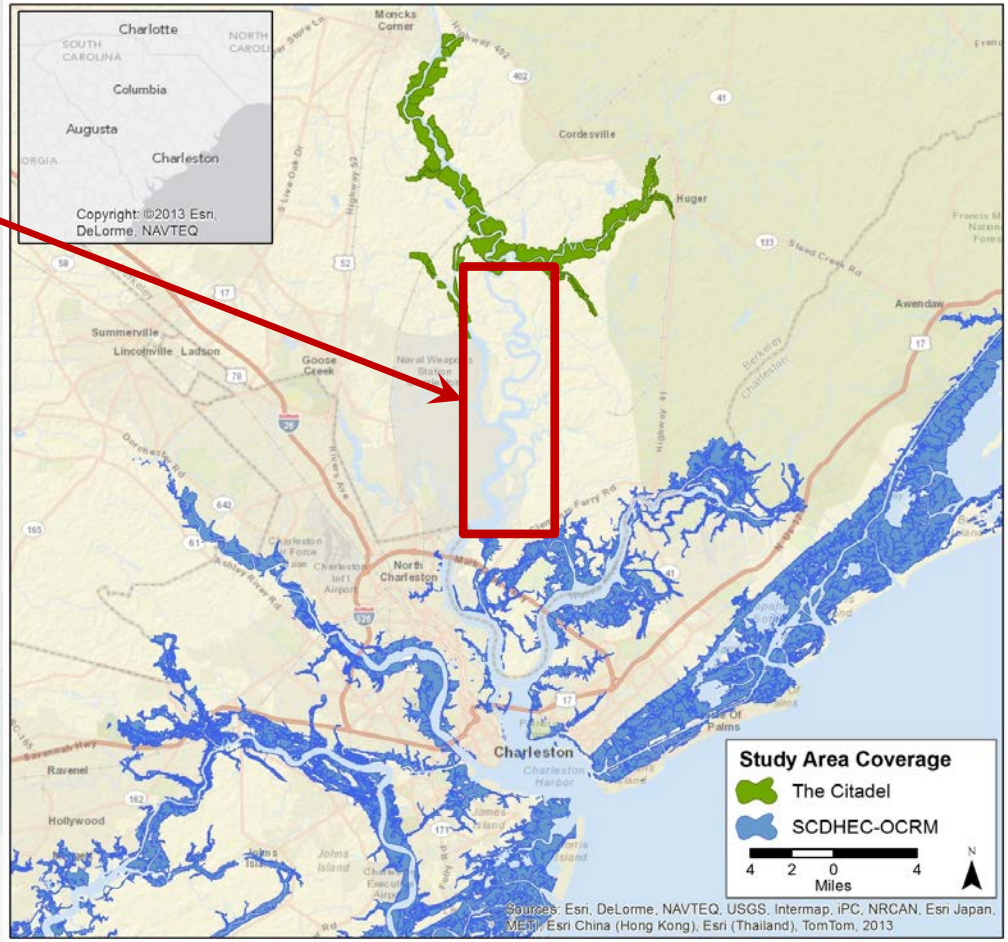
- Develop data driven tools and technology to address environmental applications
  - Data development, integration, and spatial analysis to answer questions (ex. Where is the best place to restore oyster habitat?)
    - ✓ Growing need for spatially explicit certified models*
  - New data/sensor/analytical capabilities to address complex environmental questions (ex. What new sensors can be used to identify critical habitats? How can advanced data products be used to examine project benefits/impacts across the landscape?)
    - ✓ In-house, geospatial data resources*

Terrestrial Habitat Mapping

- Identify critical coastal habitats for planning, restoration, and operational activities
  1. Identify wetland types in Charleston, SC for a harbor deepening study
     - Wetland maps used with the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model to predict changes in wetland habitat composition as a result of project alternatives
  2. Characterize barrier island communities on Hog Island, VA to provide information about environmental conditions
     - Explore the use of plants as previsible phytosensors (via vegetation indices) in vulnerable areas to provide information about terrain state and manmade disturbance (most areas of military interest are vegetated)

Wetland Habitat Mapping - Background

- Local wetland datasets left a critical area unmapped along the Cooper River, SC
  - National datasets not current or detailed enough
  - Updated wetland mapping was requested by the Interagency Coordination Team for the missing area
  - Take advantage of Corps' agreement with NGA to acquire WorldView-2 (WV-2) imagery to map wetlands
    - ✓ What can we do with the added bands?



What are we mapping?

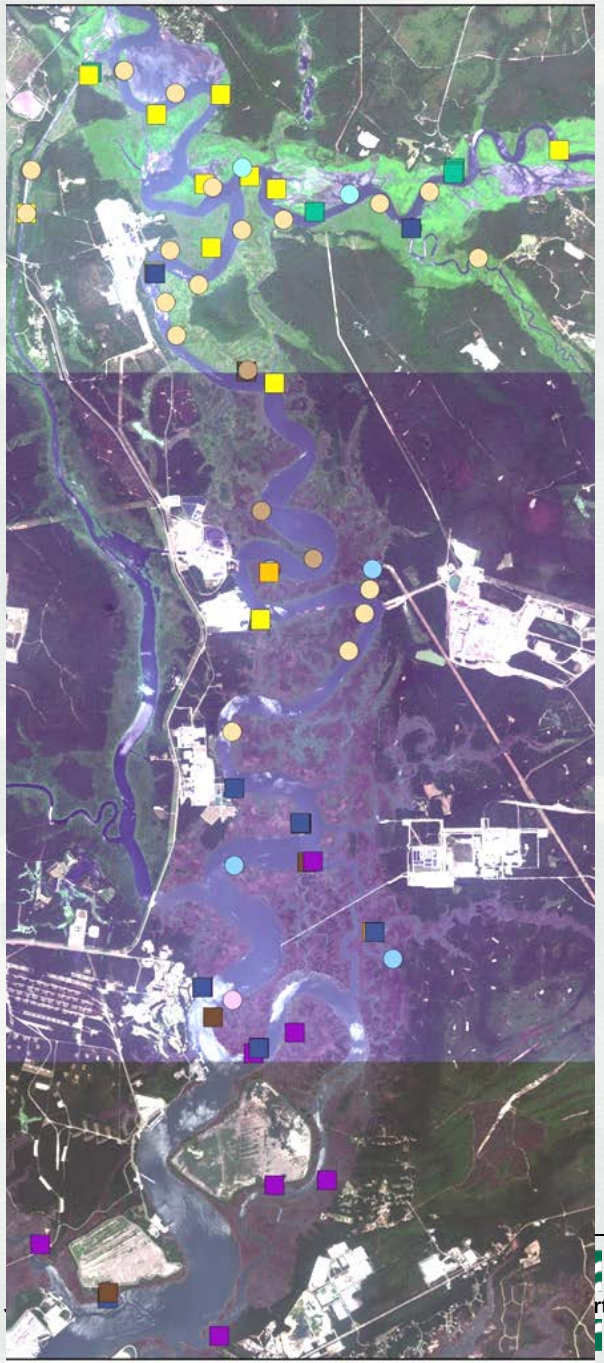
- Classification schema must be detailed enough to identify wetland types in freshwater, brackish and saltwater communities that could experience a shift in wetland structure as a result of potential hydrologic changes

Field Work

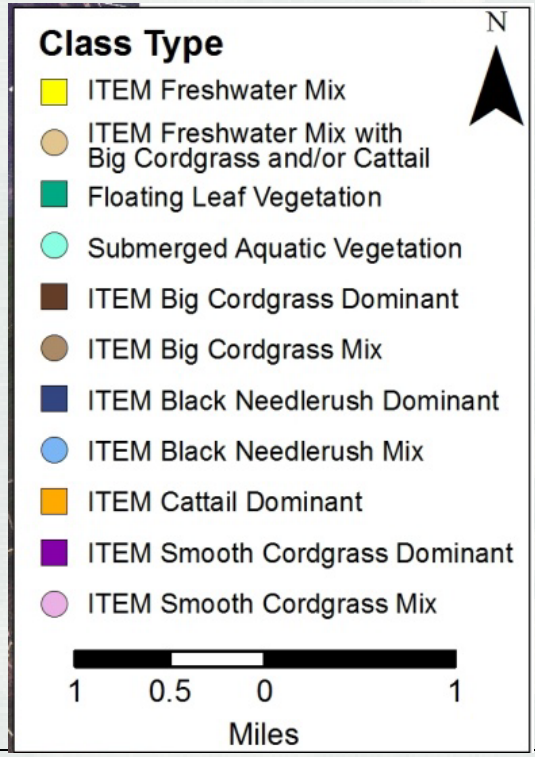
- Two field surveys conducted in December 2012 and June 2013
  - Site data collected for training (image interpretation/classification) and validation (accuracy assessment)
    - latitude and longitude using a Trimble GeoXH 6000
    - dominant wetland plant species within a 1-meter area as determined by a local wetland plant specialist
    - spectral reflectance of the dominant plant species using an ASD FieldSpec Handheld 2 spectroradiometer (visible to near-infrared), and
    - GPS tagged photographs using a Ricoh 500se camera with the SE2c GPS Antenna
  - Field surveys matched seasonal timeframes of the WV-2 imagery to minimize differences between field and image data (interannual changes were minimal and not as important as seasonal variability)

Center of Expertise

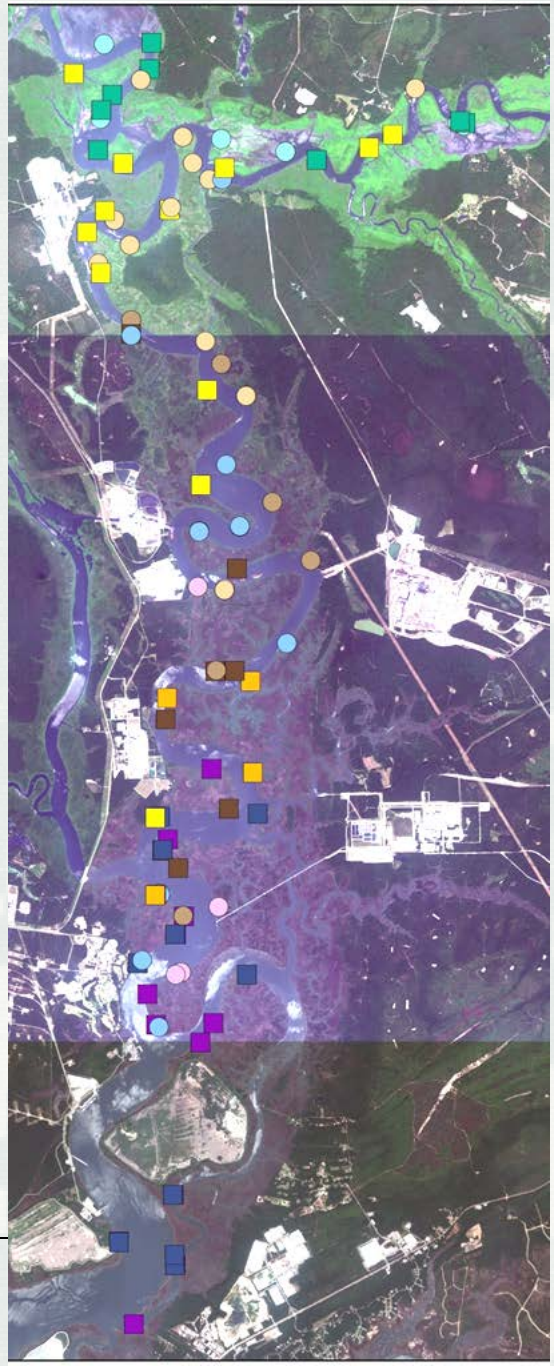
Training Sites



- December: 82 sites
- June: 136 sites (96 set aside for validation, the rest used to improve preliminary classification results in areas where there was confusion between types)

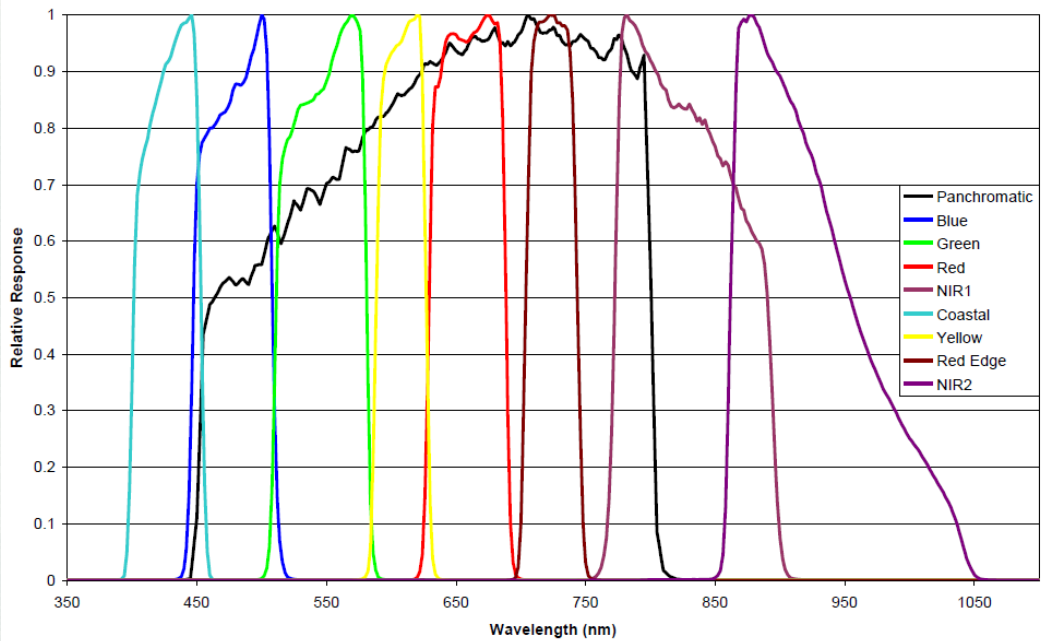


Validation Sites



WV-2 Imagery

- DigitalGlobe sensor launched Oct. 2009
- First high-res 8-band MS commercial satellite
  - 46cm pan band
  - 1.85m MS bands
  - 1.1day revisit frequency
- Designed to improve classification of land and aquatic features especially for:
  - Feature classification
  - Bathymetric measurements
  - Vegetative analysis



Panchromatic: 450 - 800 nm
8 Multispectral:

Coastal:	400 - 450 nm	Red:	630 -690 nm
Blue:	450 - 510 nm	Red Edge:	705 - 745 nm
Green:	510 - 580 nm	Near-IR1:	770 - 895 nm
Yellow:	585 - 625 nm	Near-IR2:	860 - 1040 nm

New Bands

- ❑ Red edge band can improve the accuracy and sensitivity of plant studies
- ❑ NIR2 band less affected by atmosphere; broader vegetation analysis

WV-2 Image Processing

- Convert to Radiance using ENVI's Radiometric Calibration Tool and Reflectance using the QUick Atmospheric Correction (QUAC) tool, (scene-dependent)
- Low-lying area mask created from DEM (<15ft) to extract area of interest
- Normalized Difference Vegetation Index (NDVI) used to extract wetland vegetation
  - ✓ Use Red, Red Edge and NIR2 bands in NDVI
  - ✓ Advantage to having the NIR2 band is that the difference in response values between the red and NIR regions is greater, thus widening the threshold for positive classification of vegetation
  - ✓ More bands helps more accurately mask vegetation areas of interest!

Atmospherically corrected scene, May 2011

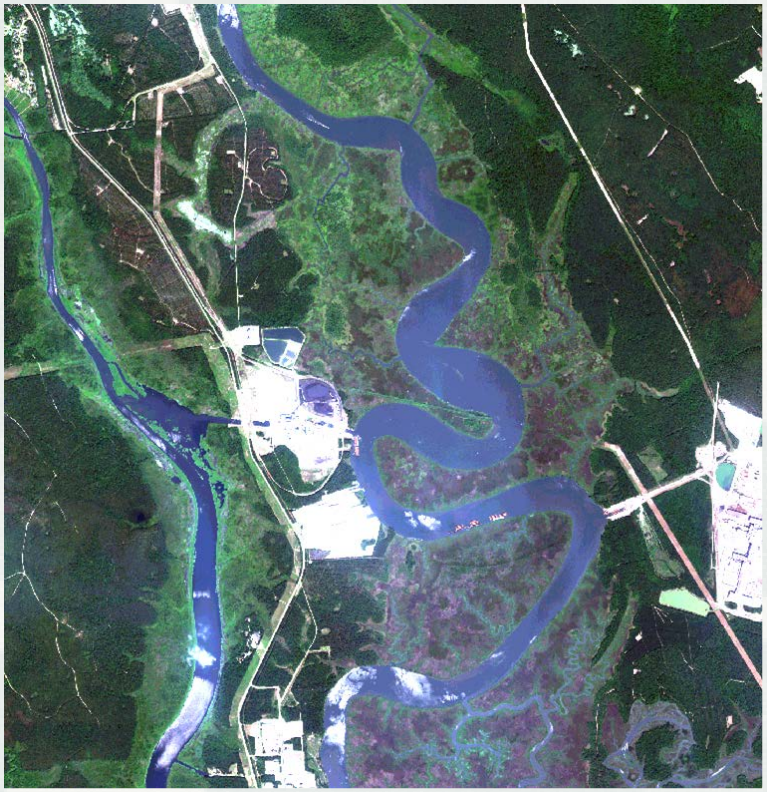
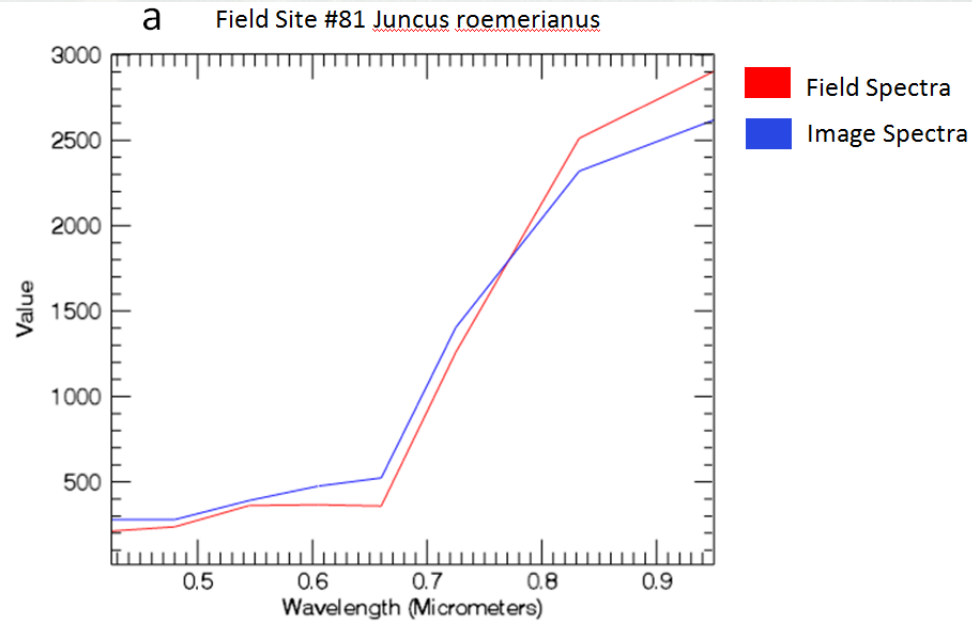
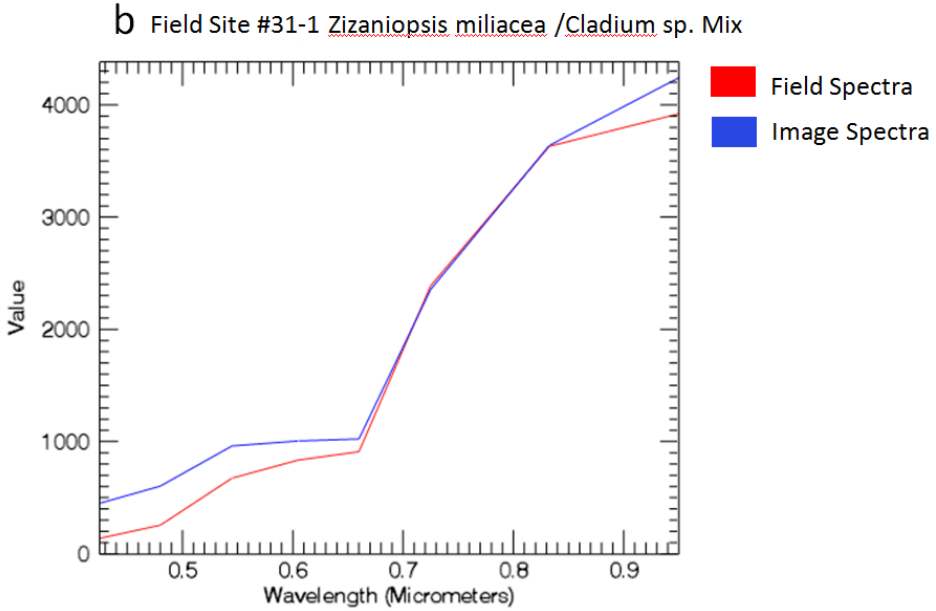


Image Classification

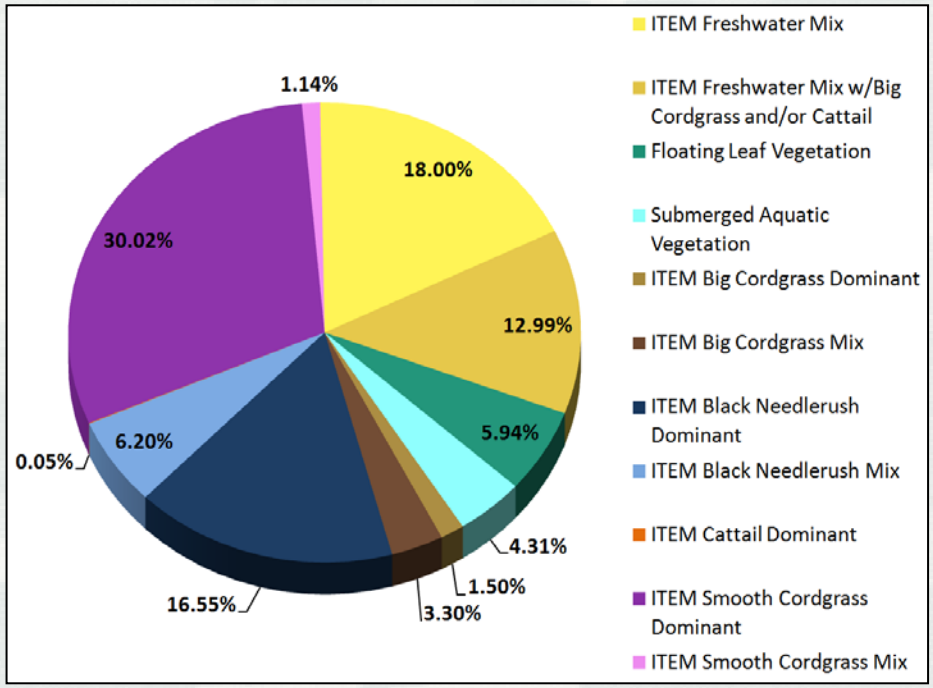
- Spectral library of the field spectra was created in ENVI to compare with the imagery (resampled to match the WV-2 band configuration)
- Spectral profiles collected in the field were compared to spectral profiles in corresponding pixels on the image
- In cases with good agreement, these sites were used to create regions of interest
- ENVI's Classification Workflow Tool (Maximum Likelihood classifier) used in supervised classification

Good agreement between field and image spectra for site 81 (black needlerush, *Juncus roemerianus*) and site 31-1 (white marsh/cutgrass, *Zizaniopsis miliacea* and sawgrass (*Cladium sp.*)

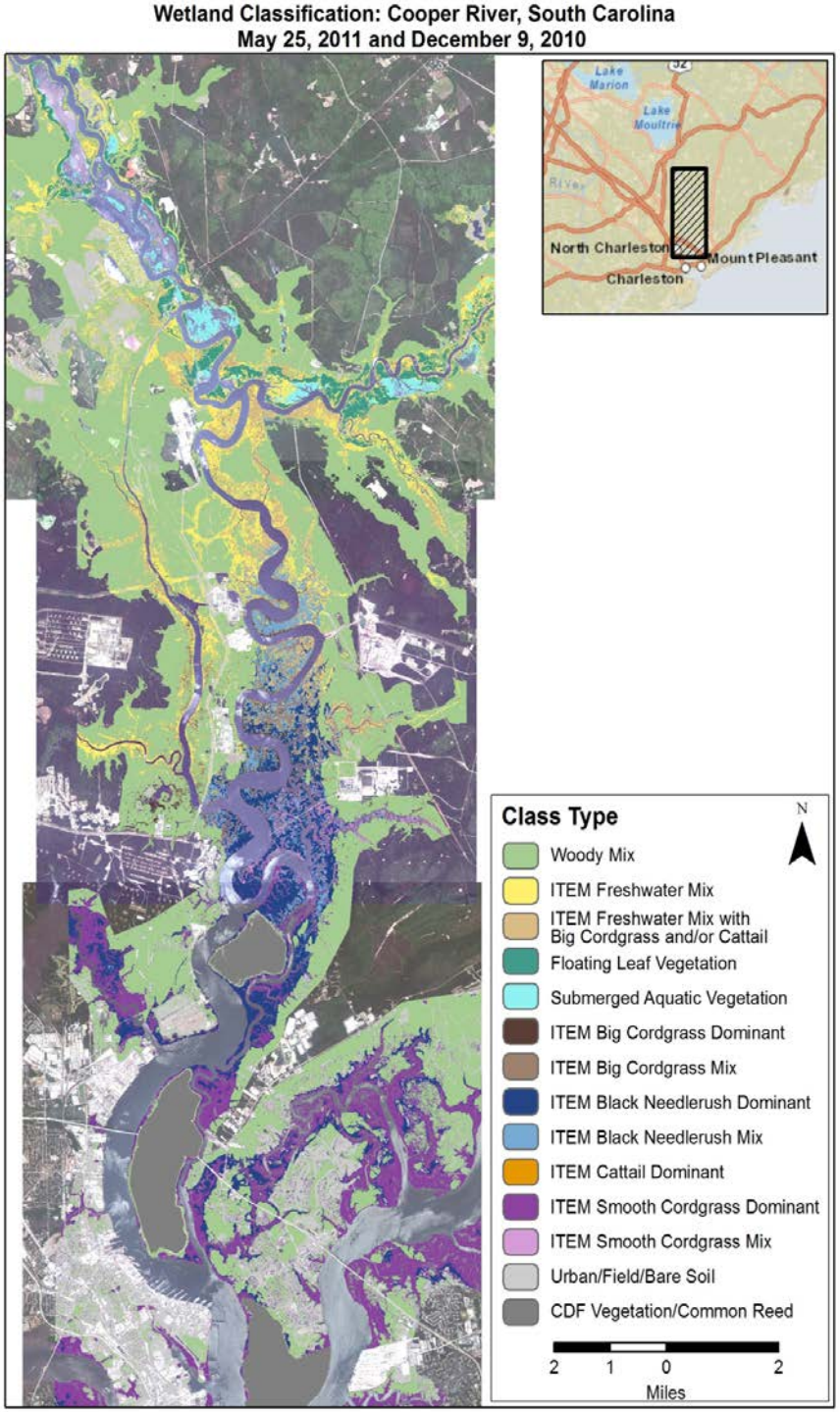




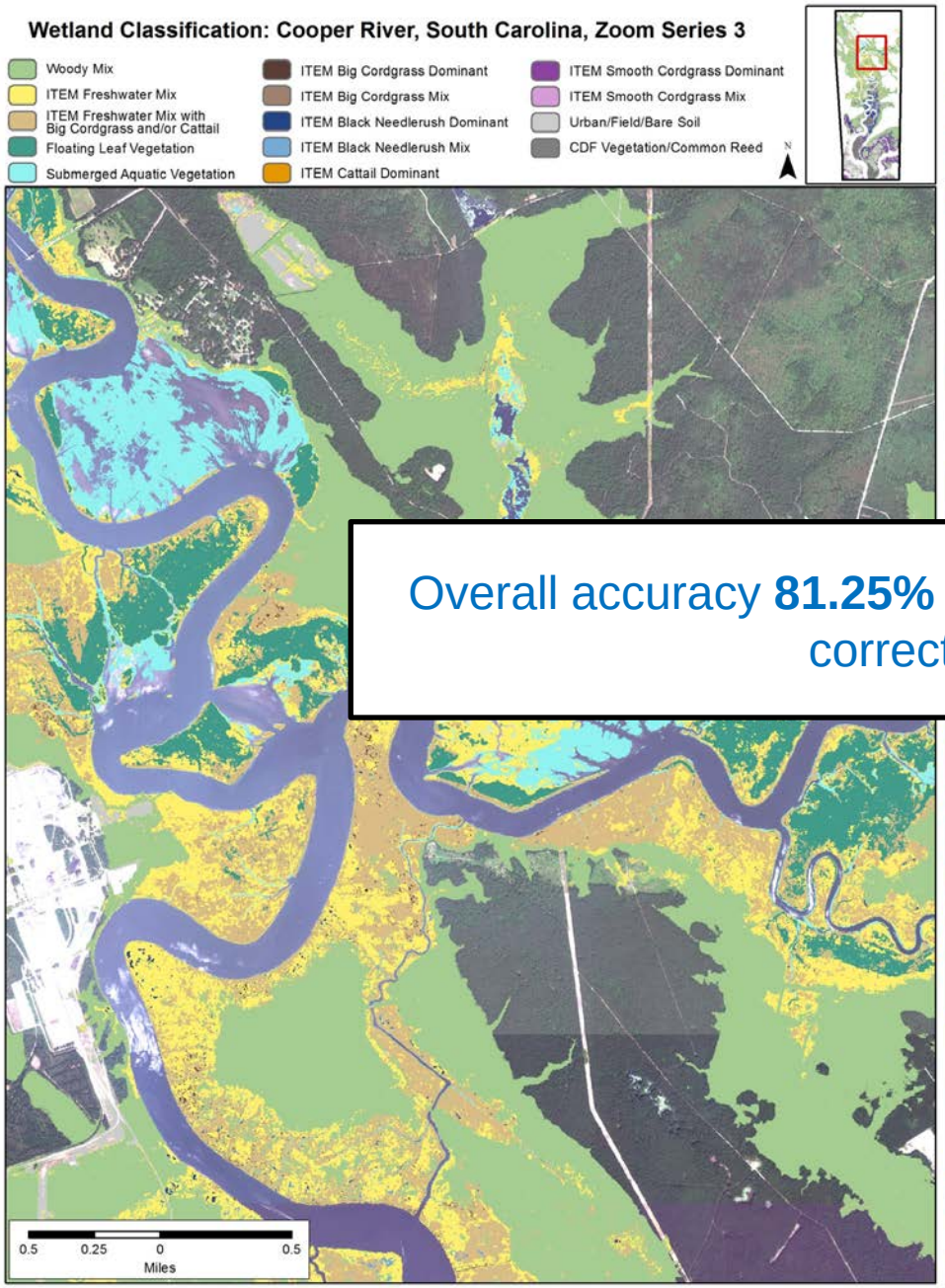
Results

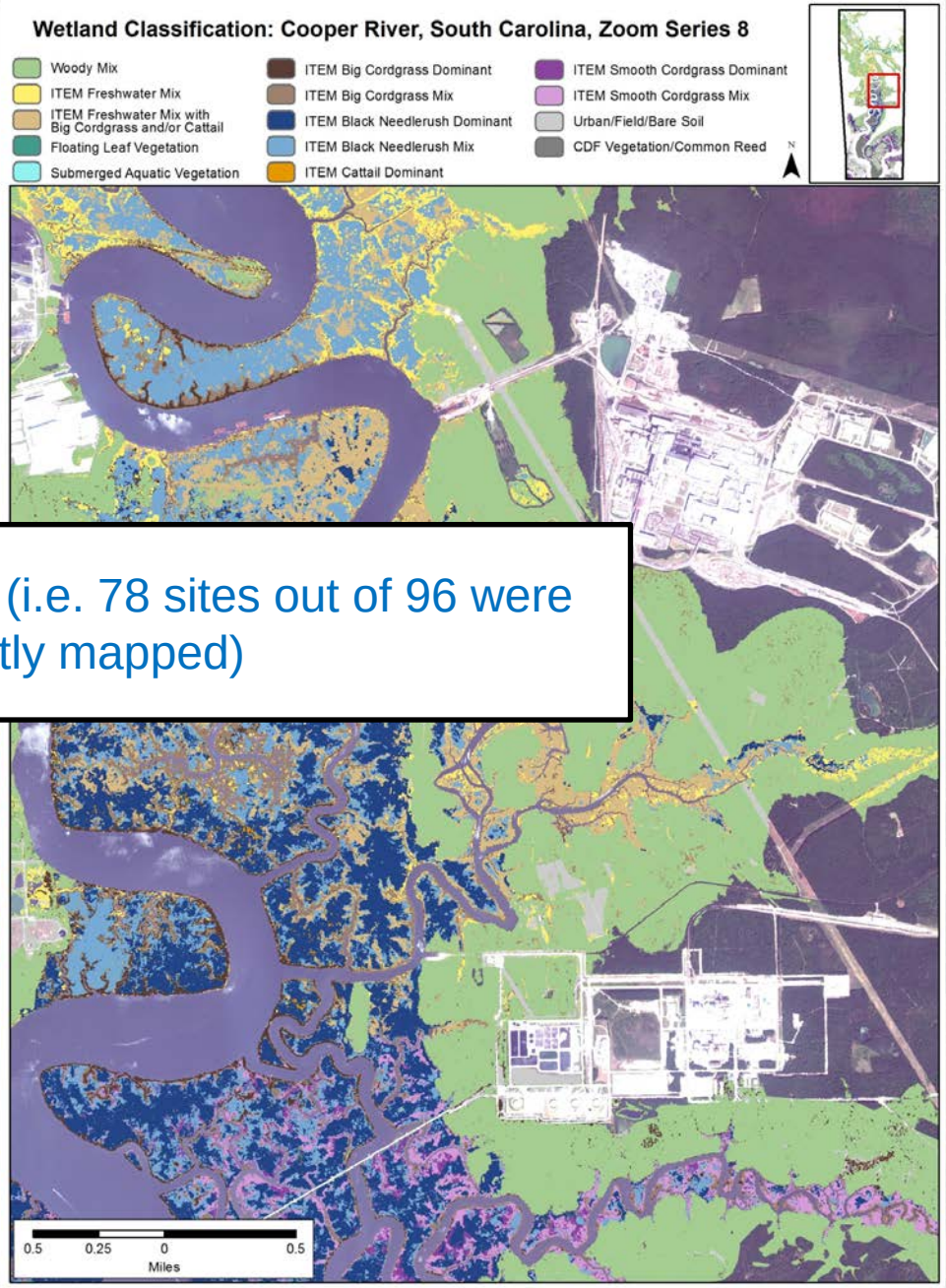


Area distribution of wetland classes (classes 2 – 12), excluding Woody Mix



Zoom Series – 2 Examples

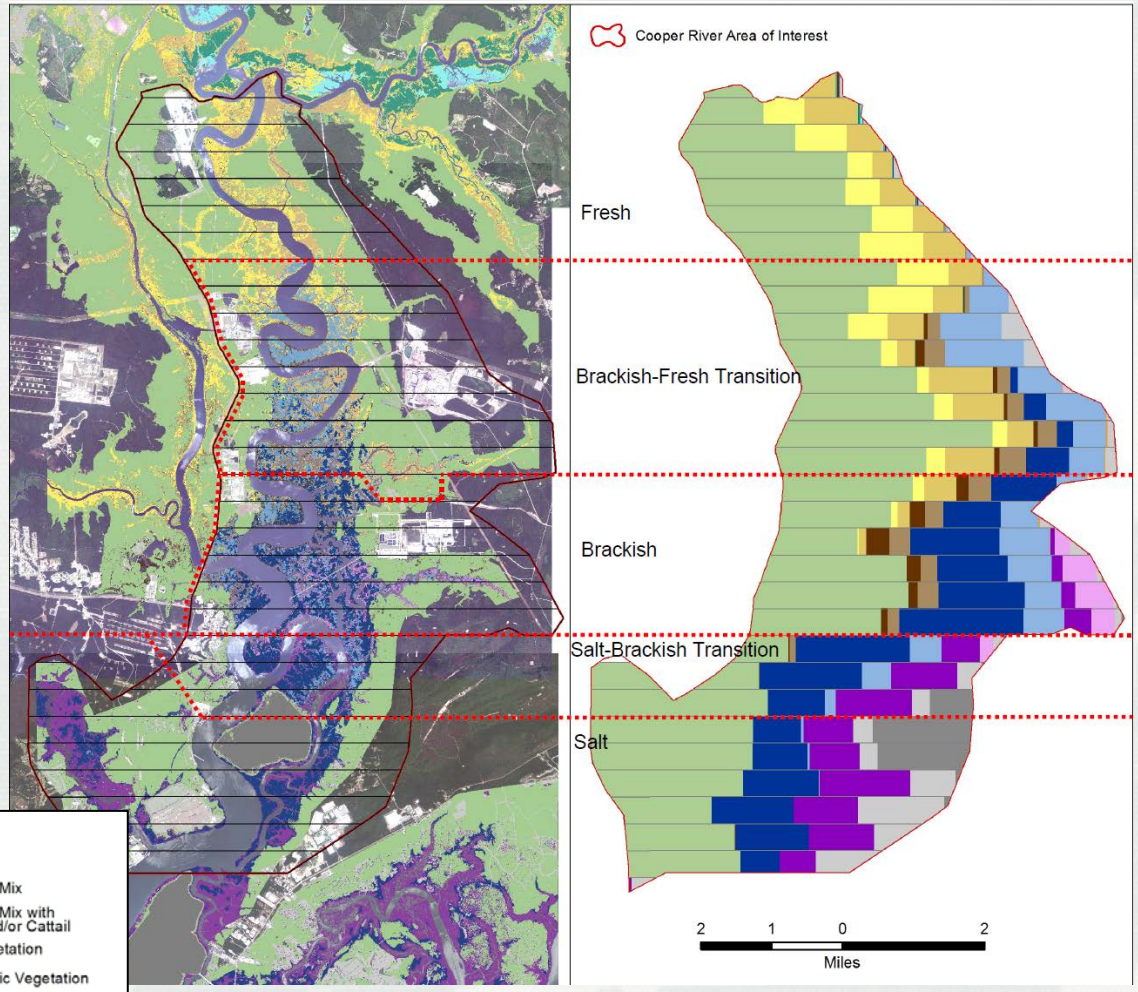




Overall accuracy **81.25%** (i.e. 78 sites out of 96 were correctly mapped)

2,000-foot Transect Analysis for Cooper River AOI

- Depict critical transition zones between freshwater, brackish and saltwater marshes:
  - 2,000-ft transect blocks delineated for an area of interest
  - In each block, the percent area of each class type was extracted
- Transect analysis illustrates wetland community distribution and abundance, and critical points of corresponding salinity changes



Class Type

- Woody Mix
- ITEM Freshwater Mix
- ITEM Freshwater Mix with Big Cordgrass and/or Cattail
- Floating Leaf Vegetation
- Submerged Aquatic Vegetation
- ITEM Big Cordgrass Dominant
- ITEM Big Cordgrass Mix
- ITEM Black Needlerush Dominant
- ITEM Black Needlerush Mix
- ITEM Cattail Dominant
- ITEM Smooth Cordgrass Dominant
- ITEM Smooth Cordgrass Mix
- Urban/Field/Bare Soil
- CDF Vegetation/Common Reed

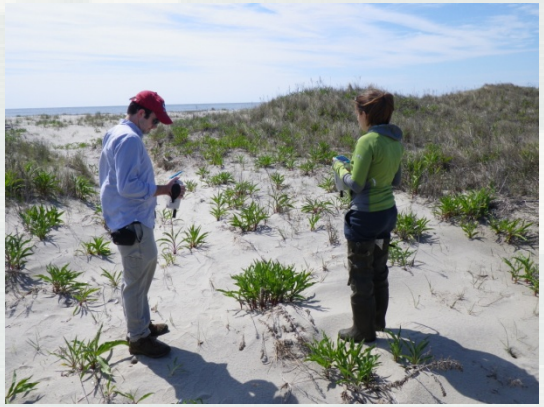
Conclusion

- Data were used to determine transitions from saltwater to brackish to freshwater wetlands
- They were combined with salinity isopleths from the hydrodynamic model to quantify potential wetland impacts as a result of project alternatives

	Alternative					
Wetland Impacts	**48/47**	**48/48**	**50/47**	**50/48**	**52/47**	**52/48**
Ashley River forested wetlands	4.88 acres	5.00 acres	5.46 acres	5.50 acres	6.80 acres	7.21 acres
Ashley River marsh wetlands	11.71 acres	11.99 acres	13.12 acres	13.20 acres	16.33 acres	17.30 acres
Cooper River forested wetlands	89.59 acres	97.46 acres	104.48 acres	111.28 acres	189.47 acres	193.52 acres
Cooper River marsh wetlands	127.49 acres	138.70 acres	148.69 acres	158.36 acres	269.62 acres	275.38 acres
Total	**233.67 acres**	**253.15 acres**	**271.75 acres**	**288.34 acres**	**482.22 acres**	**493.41 acres**

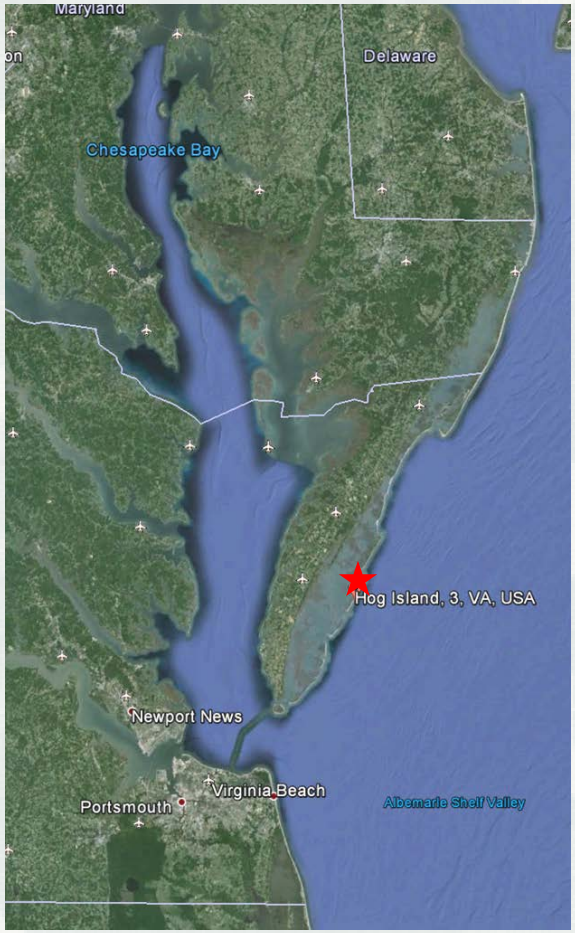
6.1 Terrain State Characterization

- Most existing research of RS to detect pre-visible vegetation health is limited to broad cover metrics of obvious physiological damage
- Advances in hyperspectral RS that focus on signatures related to pigments and biochemical/structural characteristics show promise for moving beyond traditional cover metrics
- Indices can indicate subtle changes related to plant physiology and biochemistry, providing information about environmental conditions
- GOAL: Investigate indices as indicators of spatial-temporal variability in terrain state at the landscape level (i.e. link indices to environmental parameters and quantify variation in terrain state due to plant physiological status)



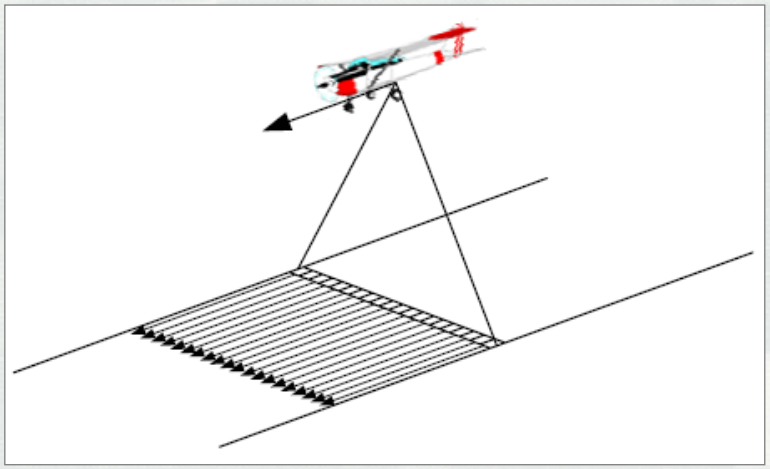
What are we mapping?

- Map 3 distinct barrier island communities on Hog Island, Virginia:
  - Evergreen Woody
  - Deciduous Woody
  - Grass

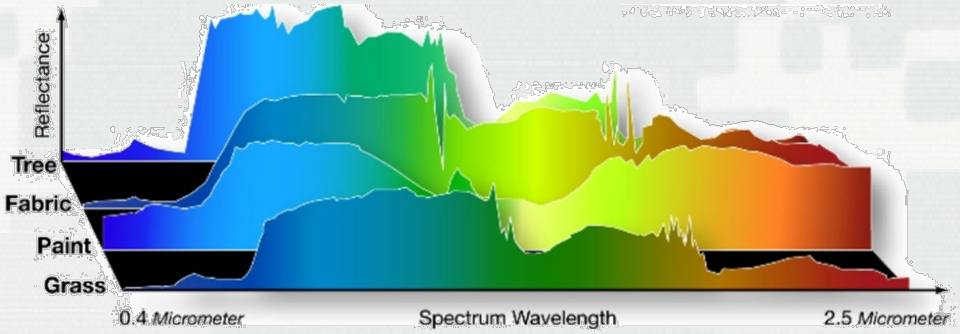


Airborne Data Collection – Year 1

- JALBTCX survey on May 14-15, 2013
- 1-meter, 48 band and 96 band hyperspectral imagery with the CASI-1500
- Topographic lidar elevation data to enhance feature identification and discrimination (image fusion techniques)



Hyperspectral sensors measure light reflected in many narrow, contiguous spectral bands across the electromagnetic spectrum. Due to the narrow bandwidth they can ***capture unique spectral signatures*** *of objects on the earths surface.*



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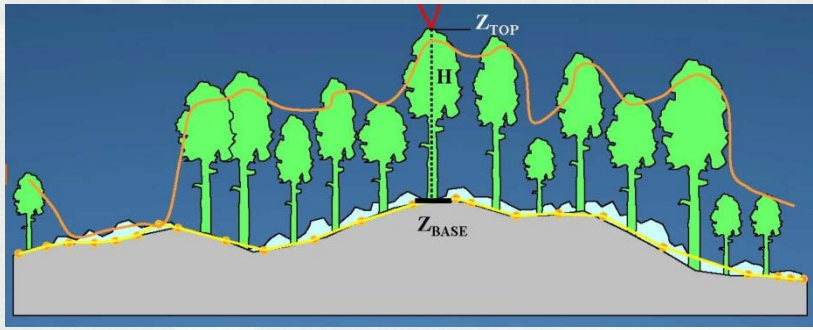
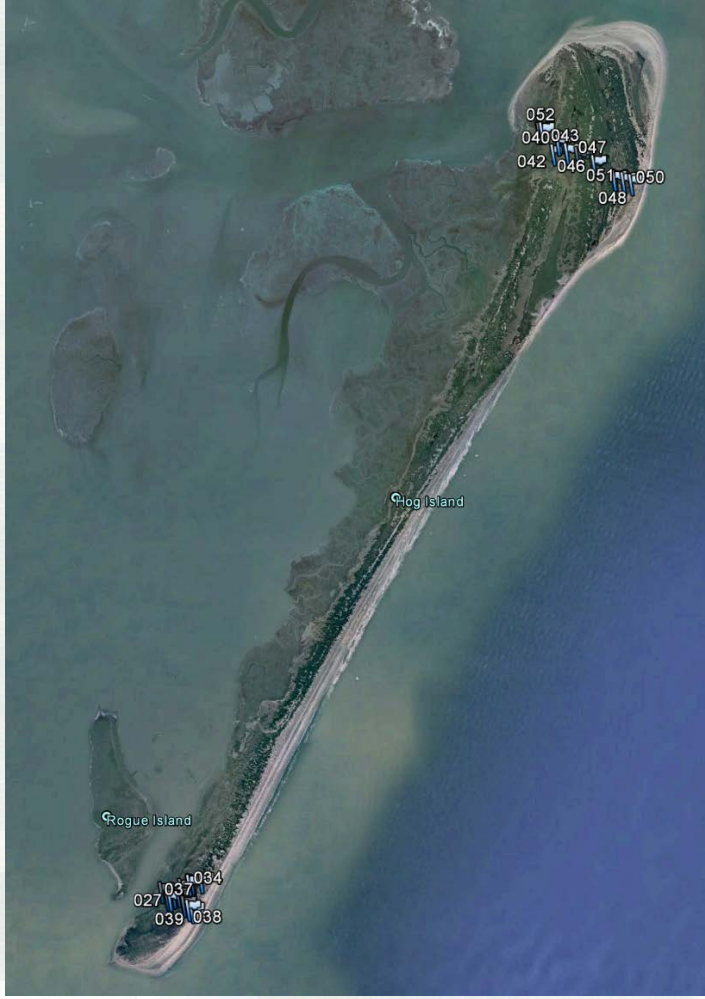


Field Data Collection

- Measurements:
  - ❑ latitude and longitude
  - ❑ GPS tagged photos
  - ❑ spectral reflectance of the dominant plant species using an ASD FieldSpec Handheld 2 spectroradiometer (visible to near-infrared)
  - ❑ Other measurements of leaf properties, etc (stomatal conductance, leaf net photosynthesis, leaf fluorescence, relative water content and pigment content)



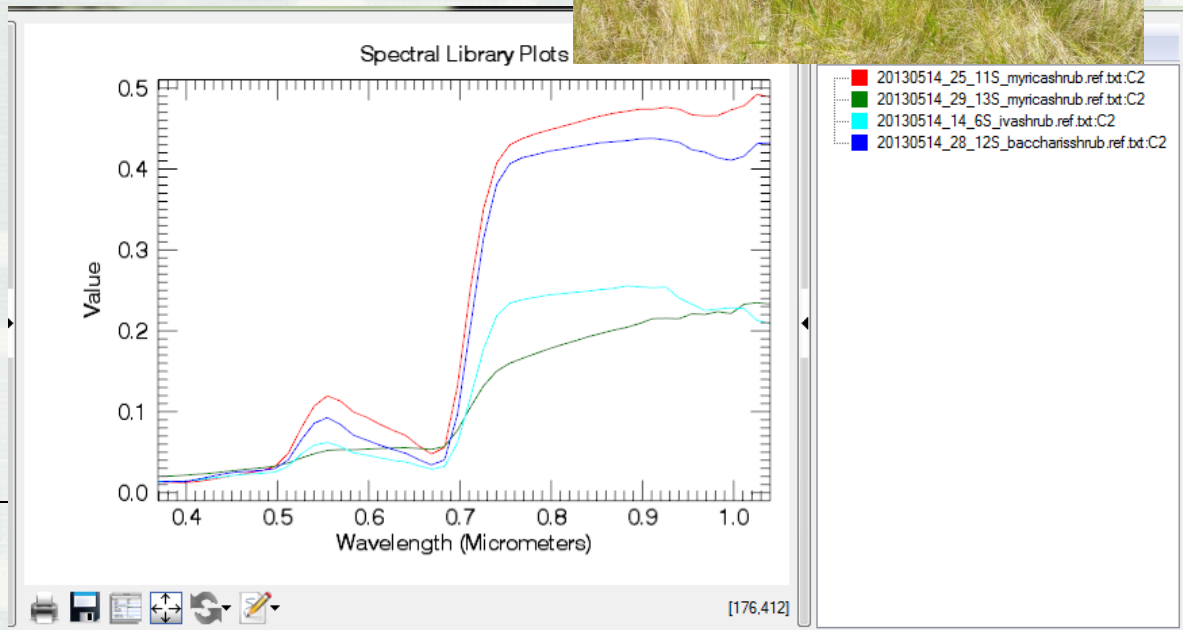
CASI Image Processing

- Geocorrection using position and orientation data collected during the flight for orthorectification
- Radiometric correction (conversion of raw digital numbers to at sensor radiance values using manufacturer's calibration techniques: ITRES Radcorr software)
- At-sensor radiance normalized to reflectance using ENVI's First Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) for comparison

Atmospherically corrected scene, May 2013

Image processing and future work

- Provided hyperspectral imagery, lidar DEMs, and in-situ spectral measurement summary to TEC
- Explore increased spectral resolution to help discriminate evergreen vs deciduous woody communities
- Conduct supervised classification to identify communities of interest
- Use lidar elevation data (height-above-ground) to improve classification results in post-processing environment



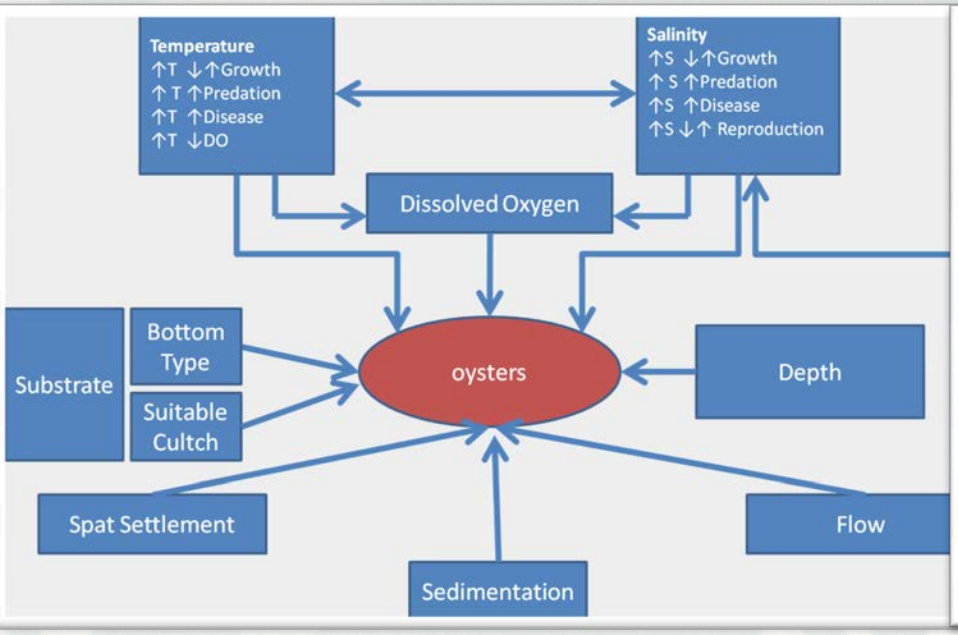
Oyster Restoration Modeling

- Oyster restoration becoming important throughout US waters
- Need to be able to plan restoration projects efficiently (i.e. need to be able to determine location of suitable habitats for oysters)
- Need to understand environmental benefits associated with restoration projects

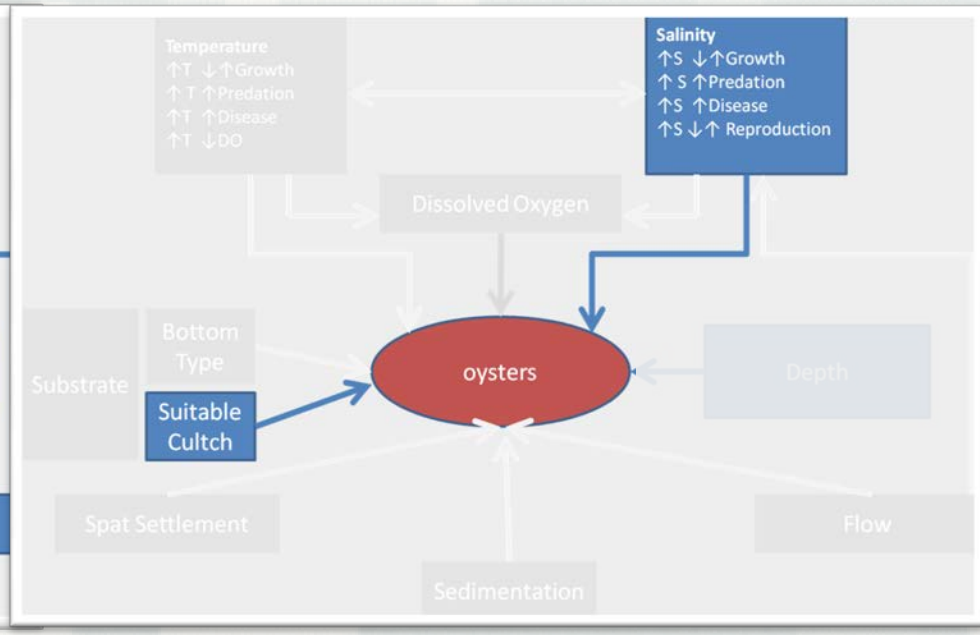
Approach

- Workshop with oyster experts throughout US in order to understand critical environmental factors for restoration
- Develop conceptual model for oyster ecology to serve as template for quantitative model
- Develop quantitative-based HSI model for oysters throughout their distribution
- Develop benefits algorithm to determine environmental benefits of proposed project alternatives

Conceptual Model



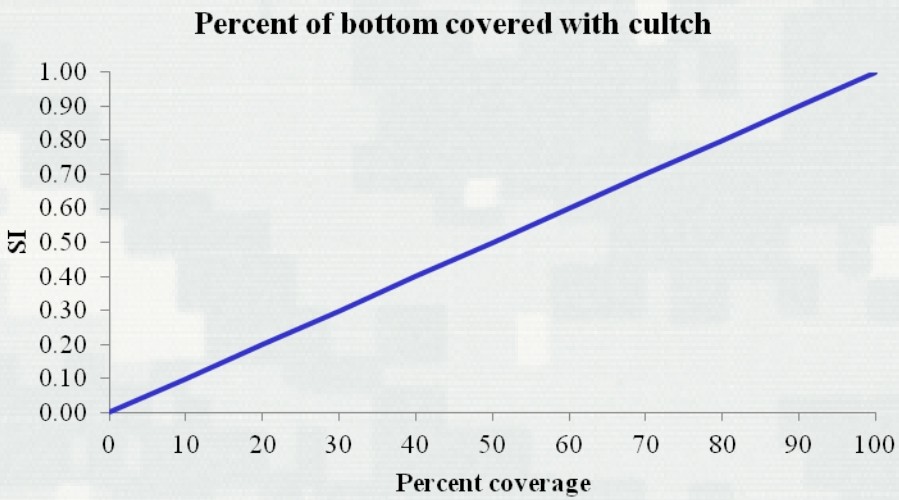
Full habitat requirements

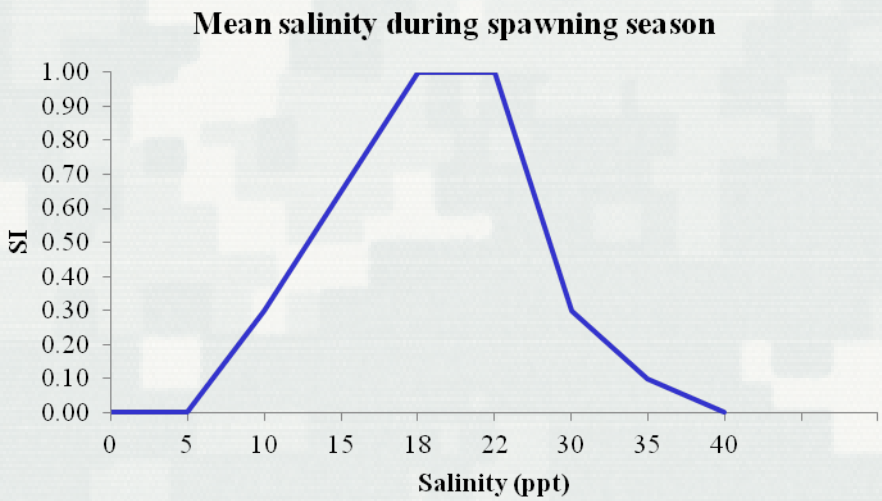


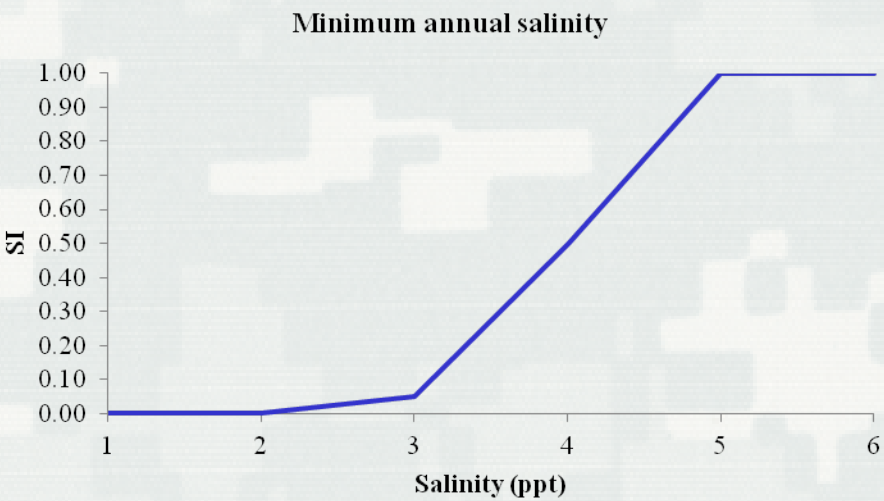
Simplified habitat requirements

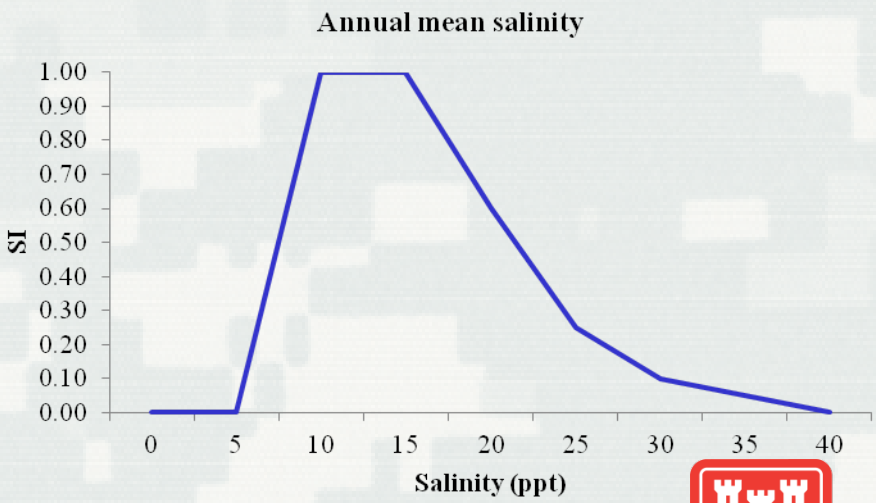
Conceptual modeling led by Dr. Tomma Barnes, Wilmington District

Model Curves



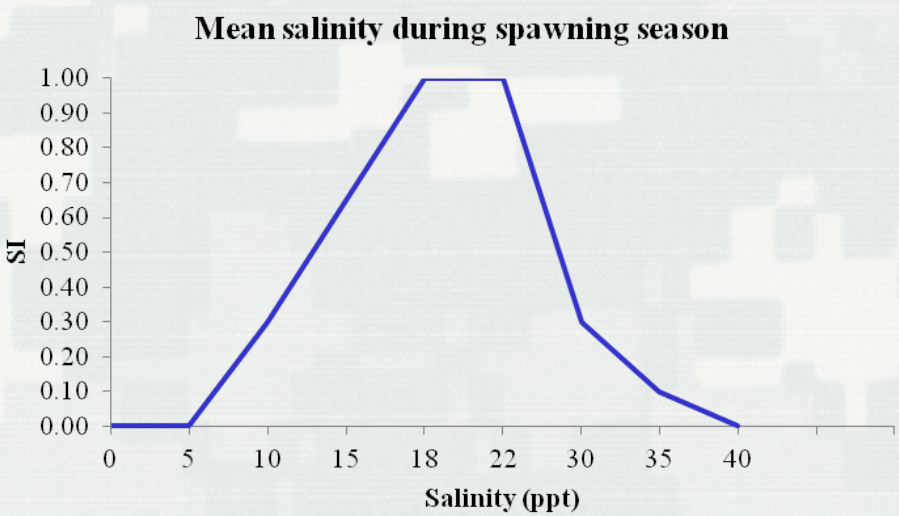






Equations

$MSSS \leq 5$ or $MSSS > 40$	$OSI_{MSSS} = 0$
$5 < MSSS \leq 10$	$OSI_{MSSS} = -0.3 + (0.06 * MSSS)$
$10 < MSSS \leq 15$	$OSI_{MSSS} = -0.4 + (0.07 * MSSS)$
$15 < MSSS < 18$	$OSI_{MSSS} = -1.1 + (0.1167 * MSSS)$
$18 \leq MSSS \leq 22$	$OSI_{MSSS} = 1$
$22 < MSSS \leq 30$	$OSI_{MSSS} = 2.925 - (0.0875 * MSSS)$
$30 < MSSS \leq 35$	$OSI_{MSSS} = 1.5 - (0.04 * MSSS)$
$35 < MSSS \leq 40$	$OSI_{MSSS} = 0.8 - (0.02 * MSSS)$



✓ **Geometric mean of all variables**

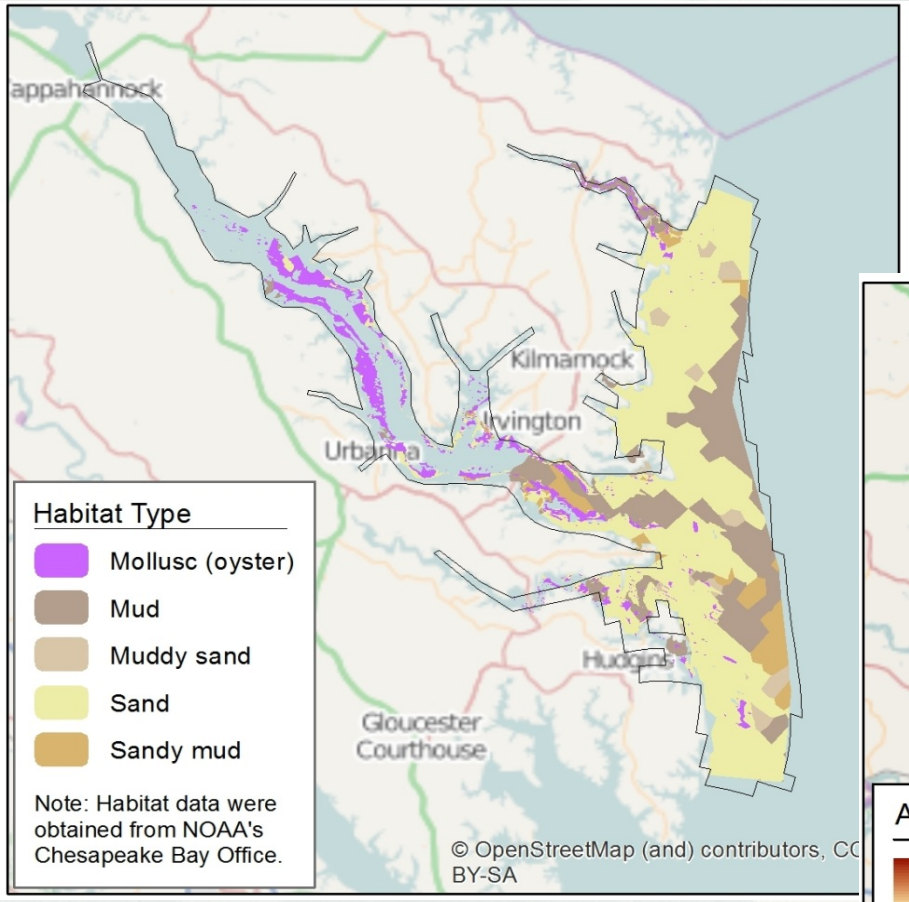
$$RSI = \left(\prod_{i=1}^{n} OSI_i \right)^{1/n}$$

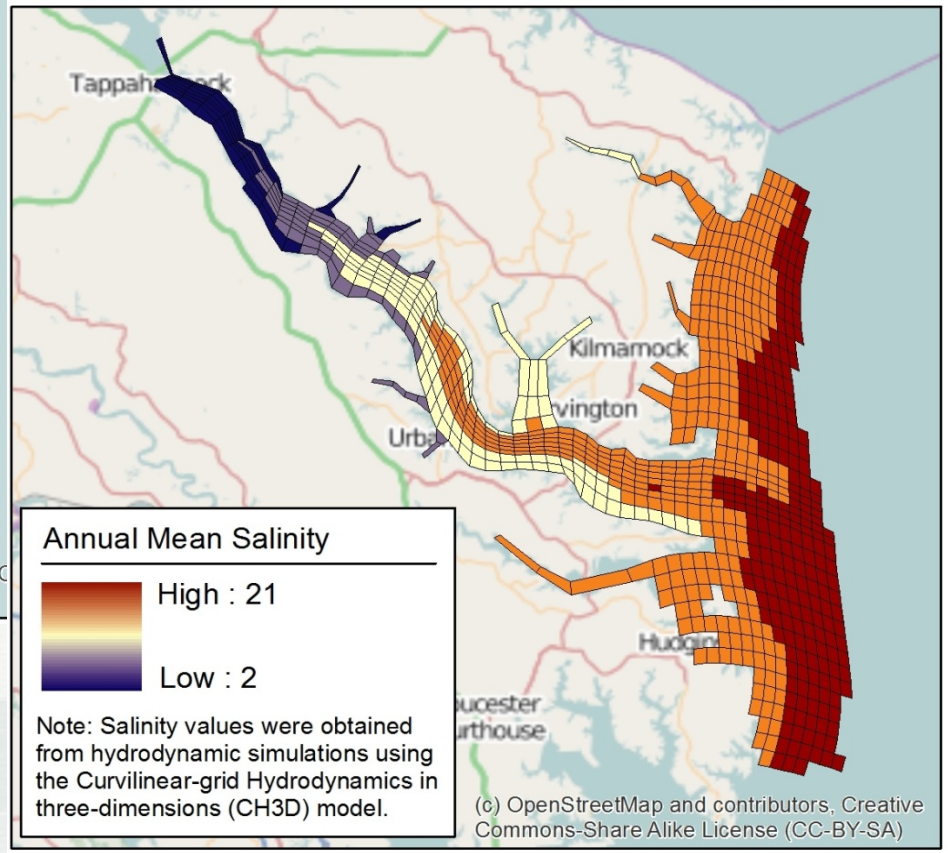
HSI – Chesapeake Bay

- **High Fidelity data**
  - Salinity (suitable salinity conditions)
  - Source: CH3D model output
  - Description: vector dataset of simulated surface salinity for 1997 – 1999 (3 years with wet, dry and average conditions) with varying grid cell resolution
  - Key variables extracted (monthly values):
    - Annual Mean Salinity
    - Mean Salinity During the Spawning Season (May – Sept)
    - Minimum Annual Salinity

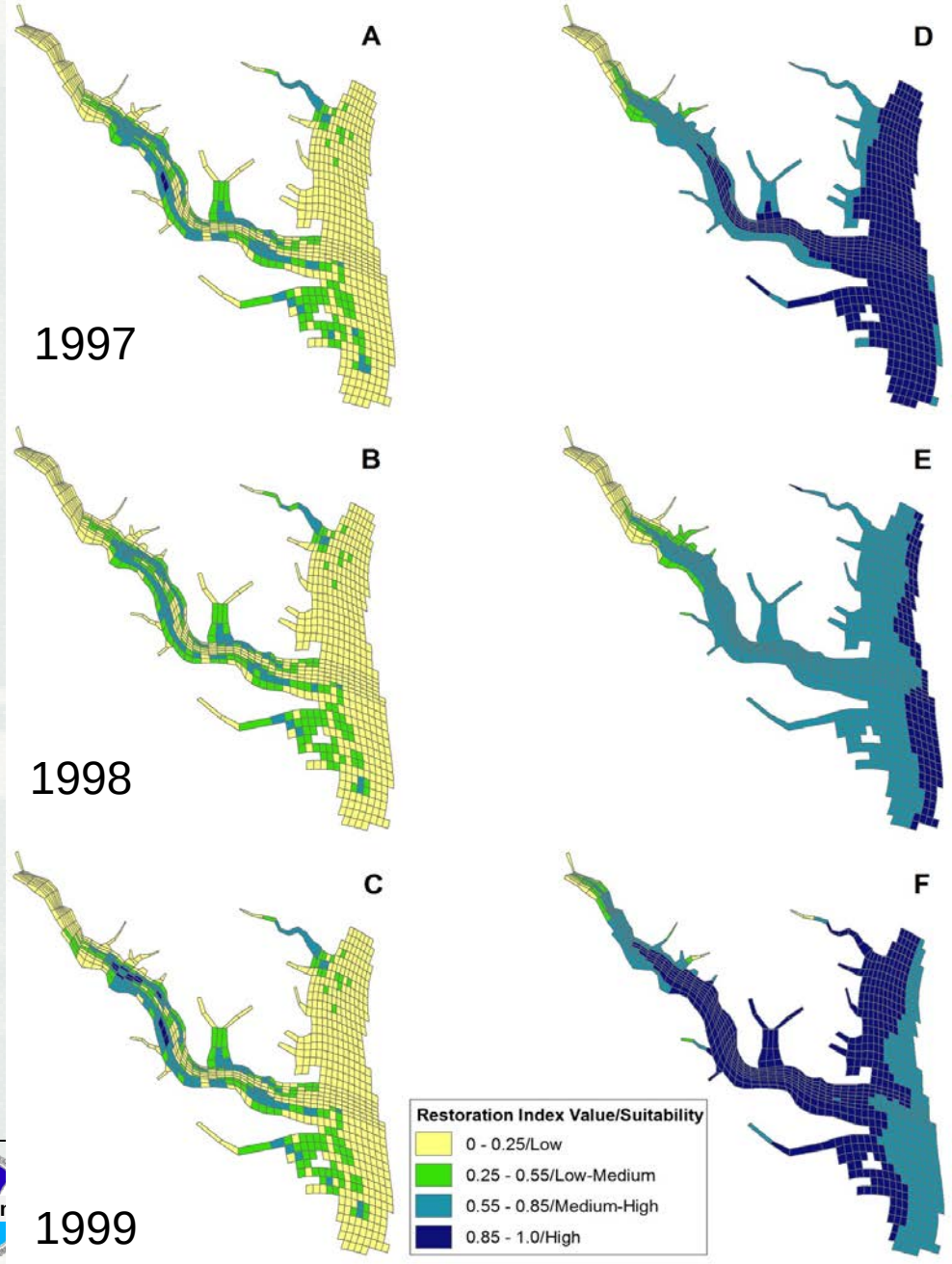
  - Cultch (potential hard bottom substrate)
  - Source: NOAA's Chesapeake Bay Benthic Habitat Integration Dataset and USACE reefs
  - Description: combination vector dataset of historic acoustic surveys from Virginia and Maryland and more recent side-scan sonar and acoustic seabed classifications
  - Key variables extracted:
    - Mollusc (oyster) polygons
    - Reefs

HSI Chesapeake Bay

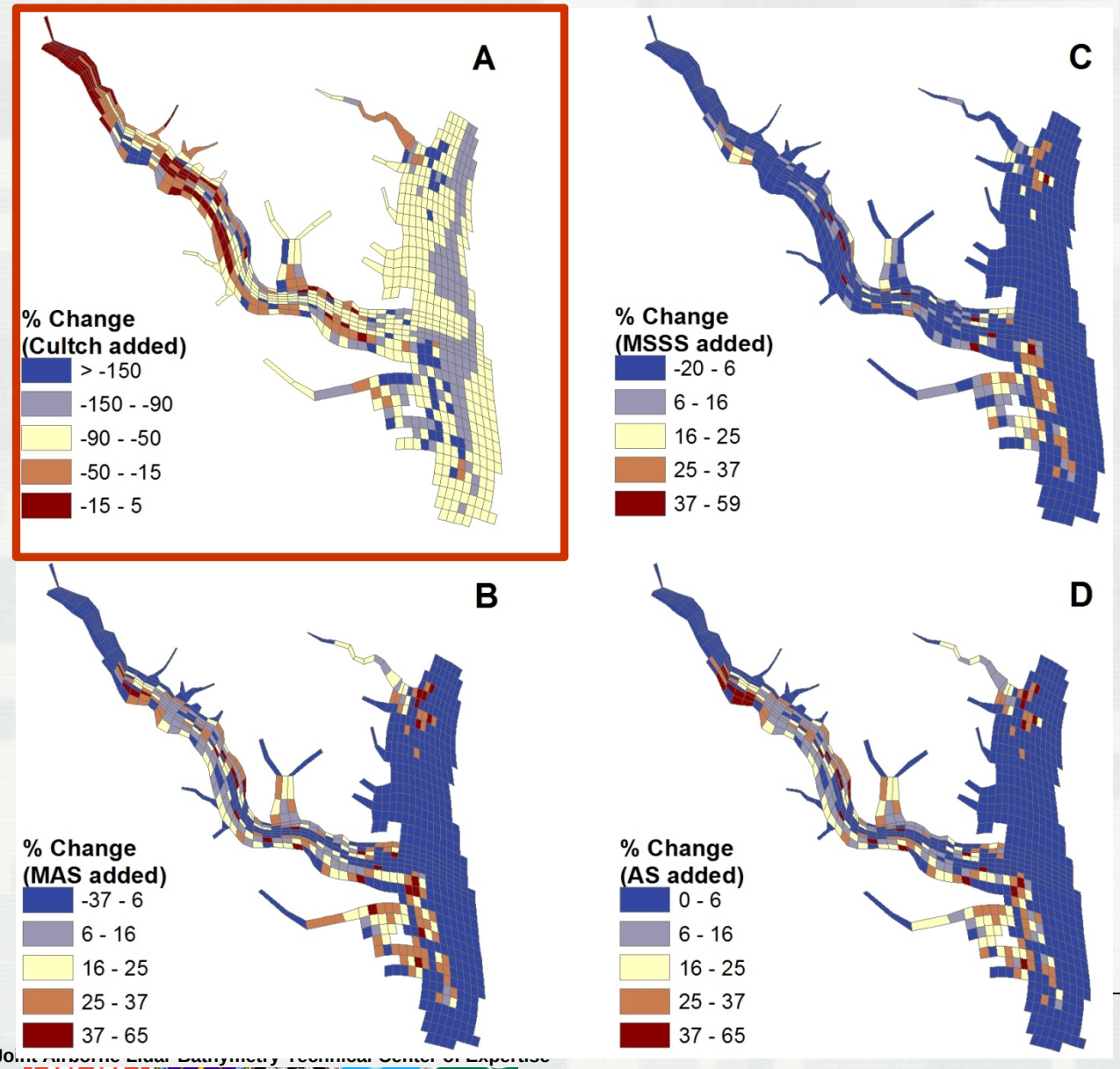




Chesapeake Bay HSI Results



Sensitivity analysis of Chesapeake Bay



Variables added one at a time, then model was rerun

Then calculated % change of results

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Conclusions and Future Work

- HSI-GIS approach is flexible and adaptable
  - ✓ Multiple data types can be used
  - ✓ Model is flexible and can be adapted as new information is available
- Important to fully evaluate model
  - ✓ Sensitivity analysis allows for deeper understanding of model results
  - ✓ Helps quantify uncertainty and make more informed decisions
- Swannack, T.M.; Reif. M.K. and T.M. Soniat. (August 2014). A robust, spatially-explicit model for identifying oyster restoration sites: case studies on the Atlantic and Gulf Coasts. *Journal of Shellfish Research*.
- Modeling oyster benefits from potential restoration work
  - ✓ Water quality parameters, among others (led by Carl Cerco and Mark Noel)

On-going and Future R&D: Water Quality Monitoring

- Support the Great Lakes & Ohio River Division's water quality monitoring program
  - ✓ Assess hyperspectral and Landsat-8 imagery to identify water quality indicators of Harmful Algal Blooms (i.e. toxic algae)
  - ✓ Limited resources for monitoring hundreds of USACE lakes/reservoirs
  - ✓ RS tools to help prioritize field-based monitoring and provide early warning system

- Approach:

1. CASI hyperspectral flight late June 2014 with coincident L8 overpasses
2. Work with the UC and NOAA to develop/refine algorithms to estimate indicators such as chlorophyll and turbidity (Bloom Index, Cyanobacteria Bloom Index, Maximum Chlorophyll Index, etc)

Priority Parameters:

* Algae sp.
    - o Identification (300 level to type/genus level)
* Enumeration(cell counts)
* Biovolume
* Toxins (microcystis)

Chl-a - micrograms per liter - laboratory analysis

ASD spectra - relative reflectance (unit-less)

* Remote sensing water leaving reflectance (RRS)

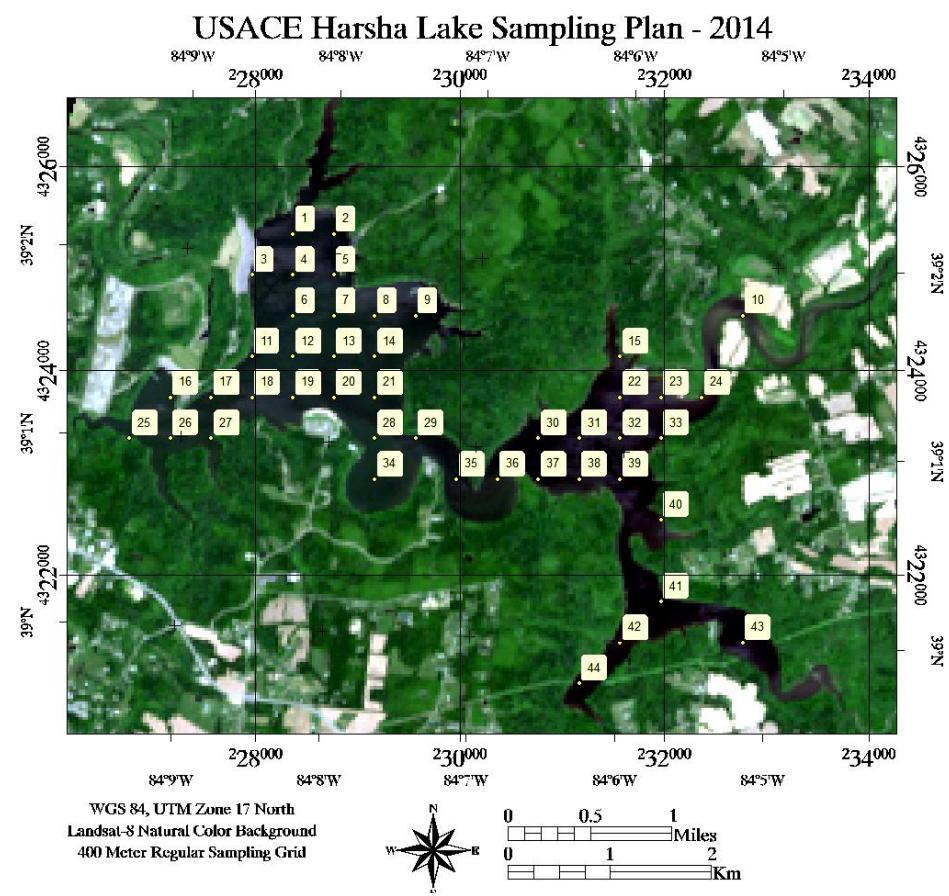
Phycocyanin - micrograms per liter

- o Field - via YSI instrumentation (crude measure of cyano presence)

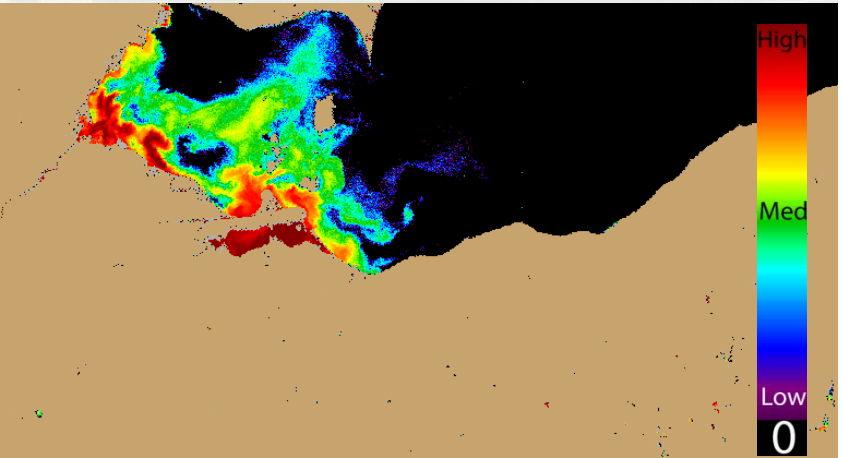
Chl-a - YSI probe measurements - micrograms per liter

- o Field - via YSI instrumentation (crude measure of cyano presence)

Turbidity - YSI probe measurements - NTUs



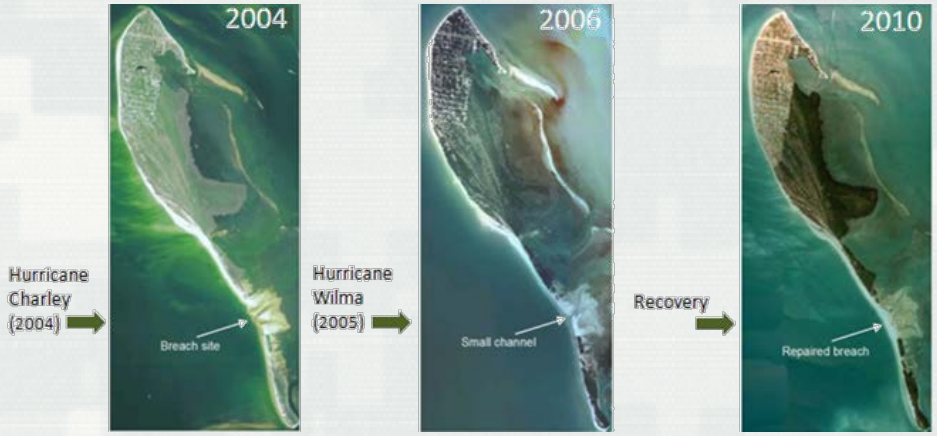
Example: southern Lake Erie (MCI)

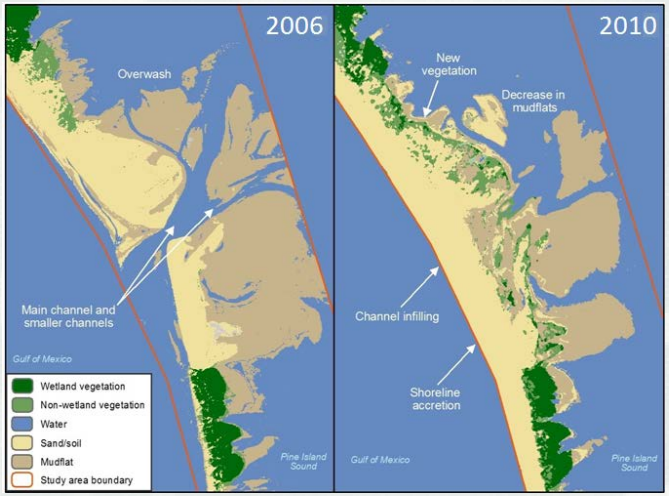


Resource	Organization			Harsha Lake	Taylorsville Lake
Boat 1	U. Cincinnati	ASD and YSI with Chl-a		yes	yes
Boat 2	KY DOW	ASD and YSIs with Chl-a and Phyco		yes	yes
Boat 3	USACE Huntington	ASD and YSI with Phycocyanin		yes	yes
Boat 4	KY DOW	Rapid Grab Water Sample and Secchi Survey	Needs Ice Chests	yes	yes
Boat 5	USEPA Cincinnati	Rapid Grab Water Sample and Secchi Survey	Needs Ice Chests		

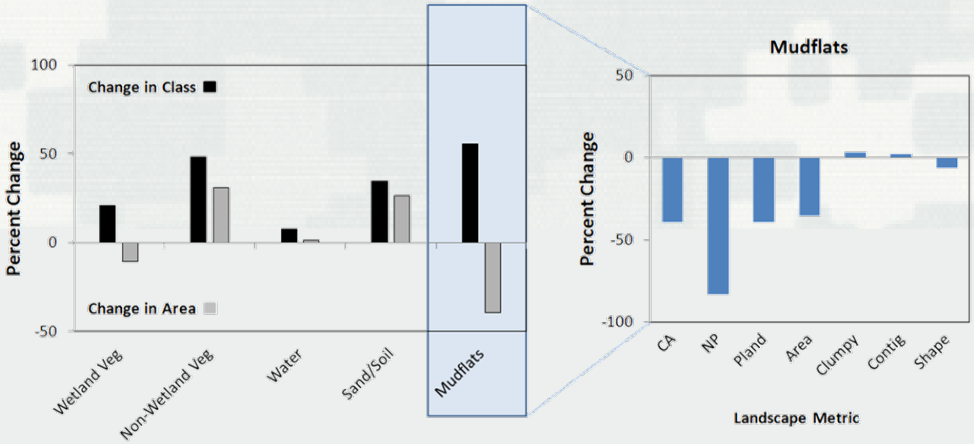
On-going and Future R&D: Ecological Modeling for landscape change analysis

1) Identify changes to critical habitat using multi-temporal imagery and lidar data





2) Derive landscape metrics associated with landscape patterns



3) Integrate with ecological simulation to develop a better understanding of factors influencing change and a tool to assess project level impacts/benefits

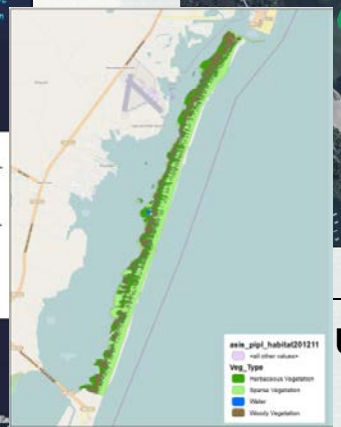
Change in Landscape Pattern

Change in Ecosystem Function

Metric	Process	Benefit
Clumpiness	Biodiversity	↑↓
Cohesion	Connectivity	↓↑

Landscape Pattern Table	Ecological Process Table	Study Table
• Pattern Type	• Broad Ecological Process	• Study ID
• Pattern Metric	• Ecological Process Name →	• Ecological Process Name
• Metric Category	• Ecosystem Goods & Services Category (UNEP)	• Temporal Scale (Study)
• Broad Metric Type	• Process Category	• Spatial Scale (Study)
	• Spatial Scale (process)	• Study metric
	• Broad Metric Type	• Habitat

- ecological process-pattern relational database to identify, organize, and quantify linkages between ecological processes and landscape patterns and metrics. Describing: 1) critical landscape patterns and metrics, 2) ecological processes, 3) specific studies citing 1 and 2, and 4) how patterns, processes and studies are linked



Questions?

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