Exploitation of Geospatial Metrics for Environmental Applications

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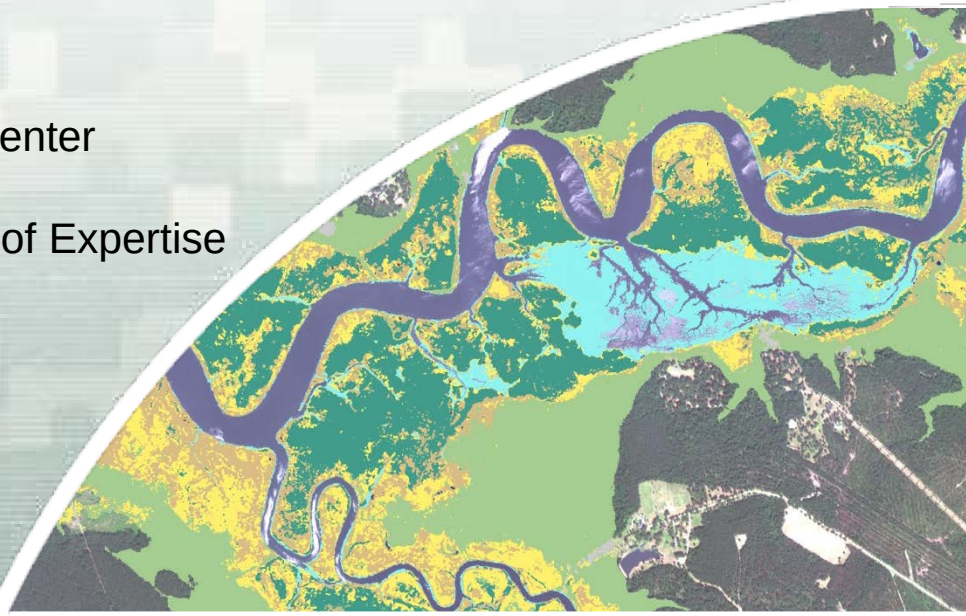
July 2016
JALBTCX Workshop



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Outline

- **What's New(ish):**
  - Growing need for spatially explicit certified models to support Planning (SMART Planning) and ecosystem restoration monitoring
    - Oysters, Salmon, Mussels, Turtles, Landscape, Fish Passage, NRDA restoration
  - Geospatial metrics for species/habitat modeling in support of restoration planning and monitoring
  - Apply spatial analysis techniques to answer questions (ex. Where is the best place to restore oyster habitat?)

- **Project Update:**
  - Charleston Harbor area wetlands mapping

Planning Models

- ✓ Plan restoration projects more efficiently
- ✓ Better understand environmental benefits from restoration
- ✓ Support integrated resource management concepts
- ✓ Assist with model certification

- Critical species (T&E, invasives, commercial) must be considered during the planning phase of a restoration project
- This requires models to assist with decision making for recommended plans (e.g., need to be able to determine suitable habitats)
- For many species, multiple models are being used, which complicates model application and certification
- Move towards systems approach, rather than single species (e.g., evaluate different outcomes at the ecosystem level as a result of project alternatives)

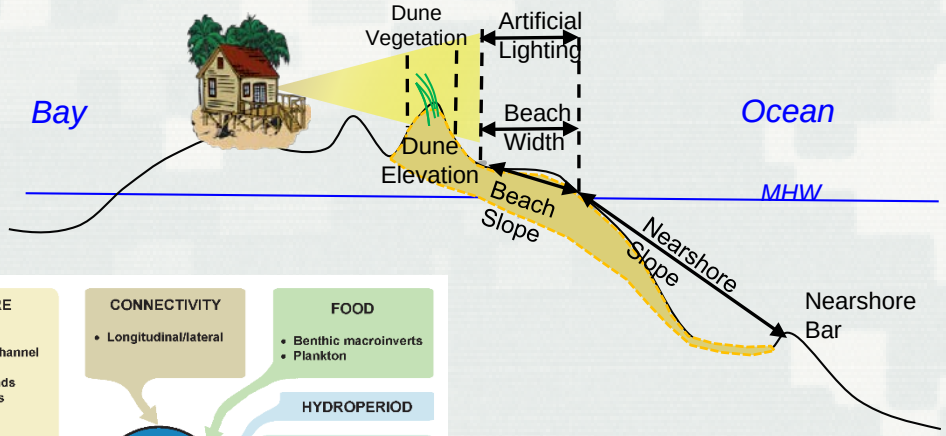
Geospatial Metrics

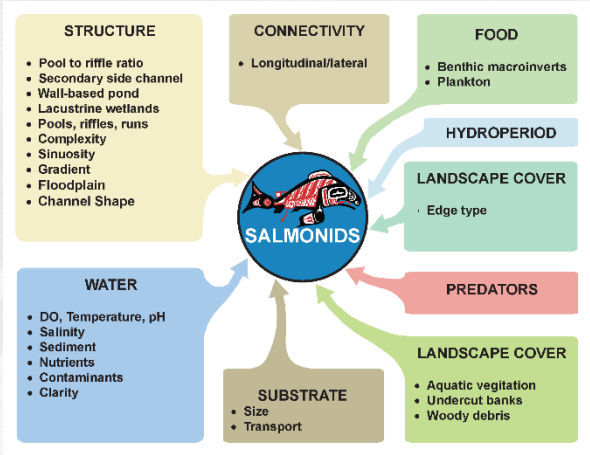
- Geospatial metrics can help streamline approach and assist planners present the recommended plan in a spatially explicit manner to better communicate benefits of plan

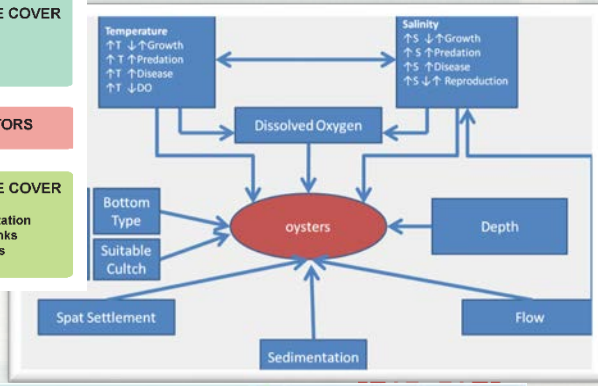
Geomorphic: elevation/depth, slope, dune characteristics, beach width, substrate size, volume/elevation change, distance to shoreline or dune peak, foredune continuity, channel shape/gradient and other structural characteristics

Environmental: terrestrial and aquatic habitat/vegetation type (e.g., SAV, wetlands), TES, invasives, cover density/diversity, fragmentation/connectivity, substrate type, impervious surface, height of vegetation above ground

Water: stream length, watershed size, salinity, turbidity, chlorophyll, toxicity exposure



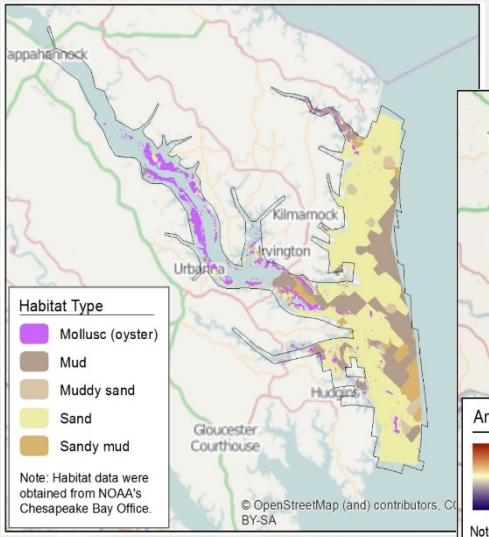


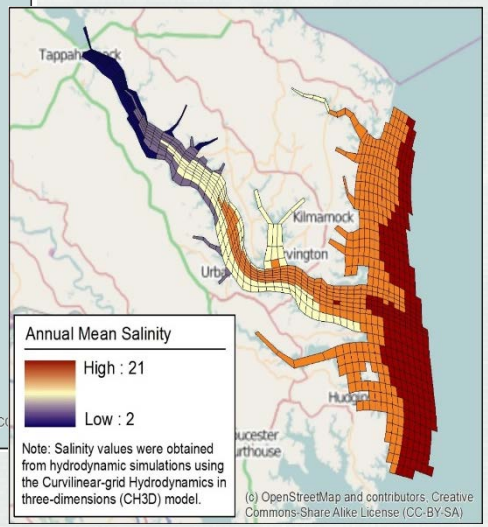


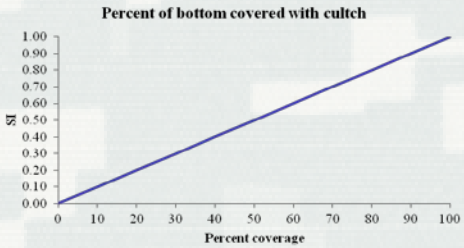
Model Examples

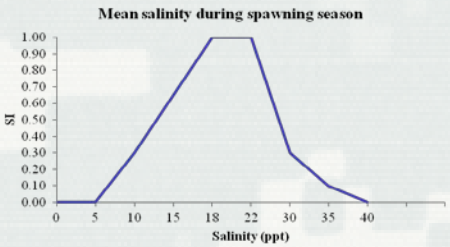
Oyster Restoration Suitability Index

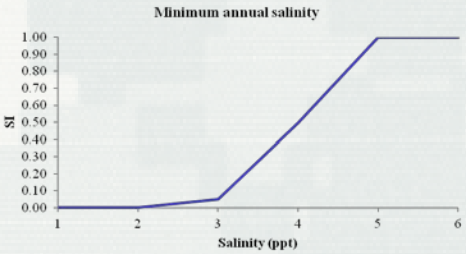
$$RSI = \left(\prod_{i=1}^{n} OSI_i \right)^{1/n}$$

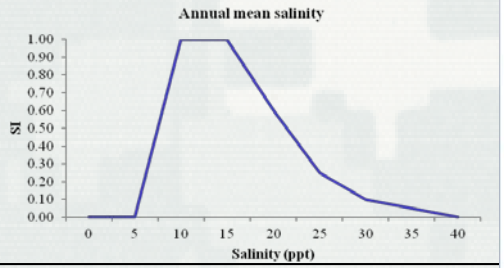


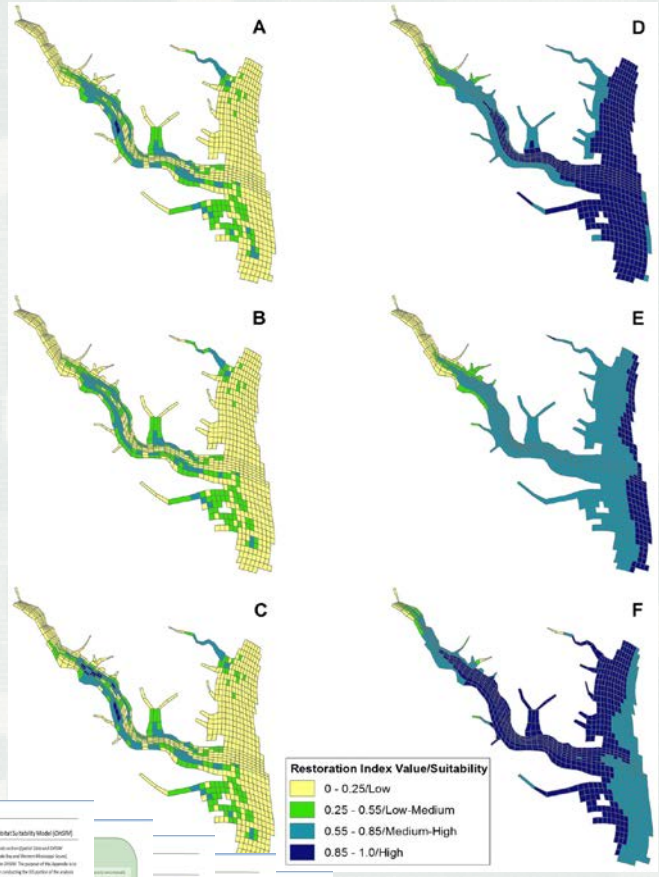












Swannack, Reif and Soniat. 2014.

Model Examples

- Develop a general standard planning model to assess proposed alternatives for ecosystem restoration projects focused on Salmonids and associated species of concern within the Pacific Northwest

- ✓ Lower Willamette
- ✓ Skokomish
- ✓ Skagit
- ✓ Willamette Floodplain

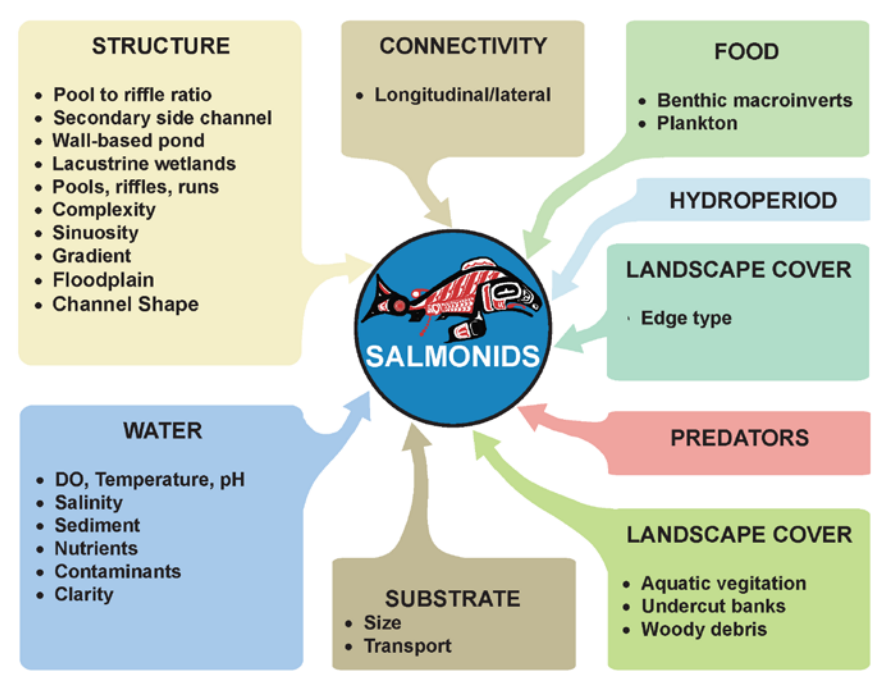
General Standard Model

Landscape Units:
Tributary, Mainstem, Estuary

Life Cycle Stage:
Spawning/Egg Incubation, Fry, Juvenile/Smolt, Adults

Parameters:
Structure, Connectivity, Landscape, Refuge Cover, Predators, Substrate, Hydroperiod, Water

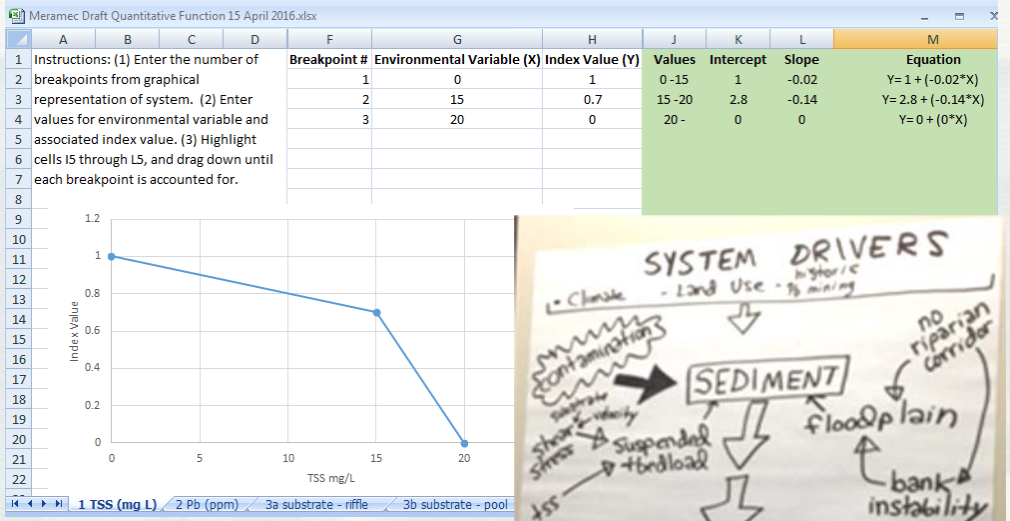
- **2014 Workshop**
  - ➢ Limiting Factor Analysis
  - ➢ Ecosystem Drivers of Critical Parameters
  - ➢ Development of Refined Conceptual Model
- **2015 Evaluate Conceptual Model**
  - ➢ Identify Potential Redundancies, Ability to Efficiently Measure, Sensitivity to Restoration
- **2016 Parameter Quantification**
  - ➢ Coming Interagency Workshop

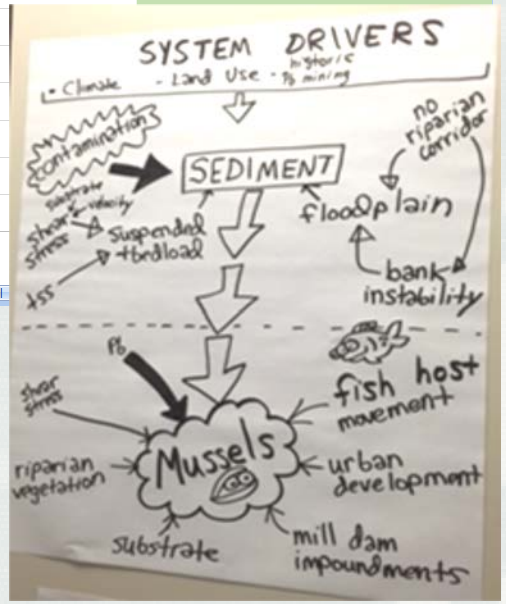


Model Examples

2016 St. Louis Mussel Workshop

- Met with 3 different project teams
- Identified environmental drivers and developed conceptual models
- Worked through model curves using expert-derived equations



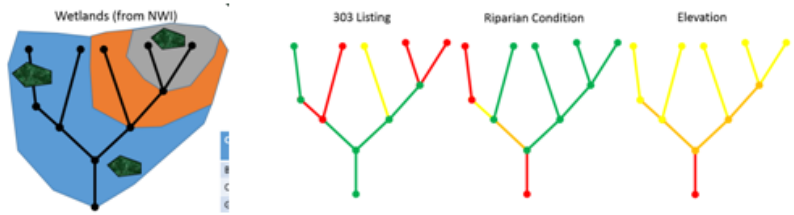


Fish Passage Restoration Prioritization

- Assess fish passage barriers, habitat quality, and prioritize sites for restoration of fish passage at barriers in the Hudson-Raritan Estuary consistent with the National Ecosystem Restoration Plan

Dam ID	Cumulative Passage Rate above this dam	Length of stream Upstream of this dam (ft in NHD)	Quality of the Stream and watershed upstream of this Dam

Quality = Average of reach-scale and catchment scale variables



Catchment properties

e.g., % wetland, % urban, % contaminated

Reach properties

e.g., % high elevation, % 303d listed

Total Quality

Eventually convert these attributes to a similar scale (e.g., 0 to 1) to combine into an overarching notion of habitat quality

Model Examples

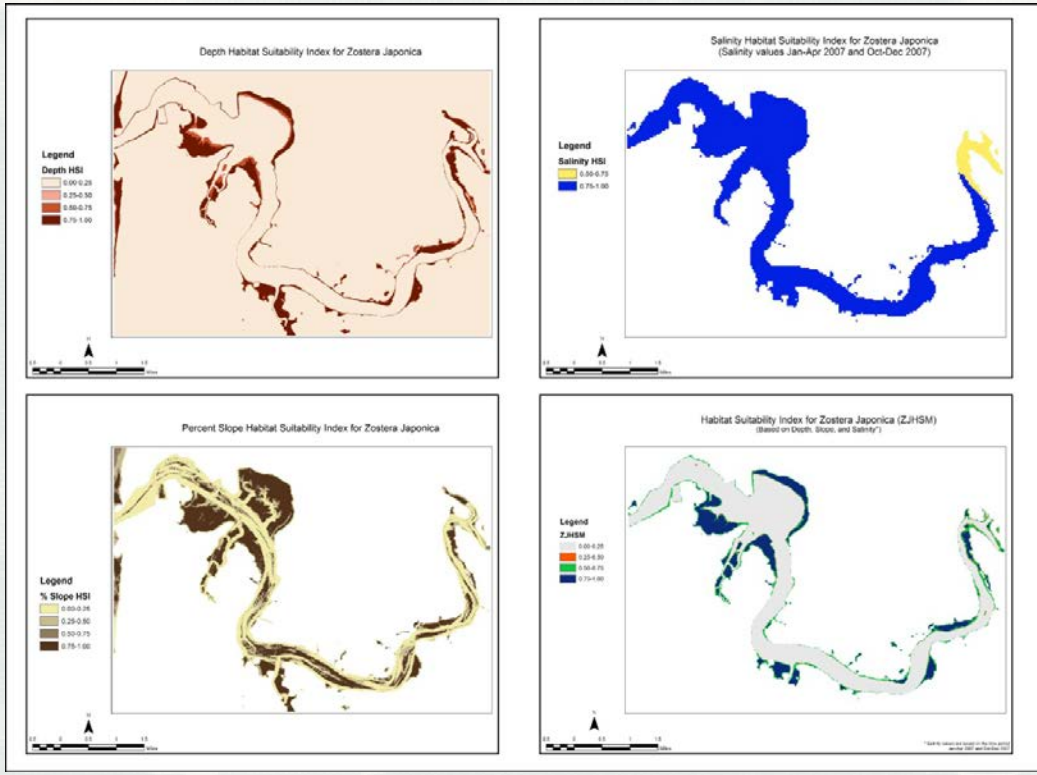
Change in Landscape Pattern

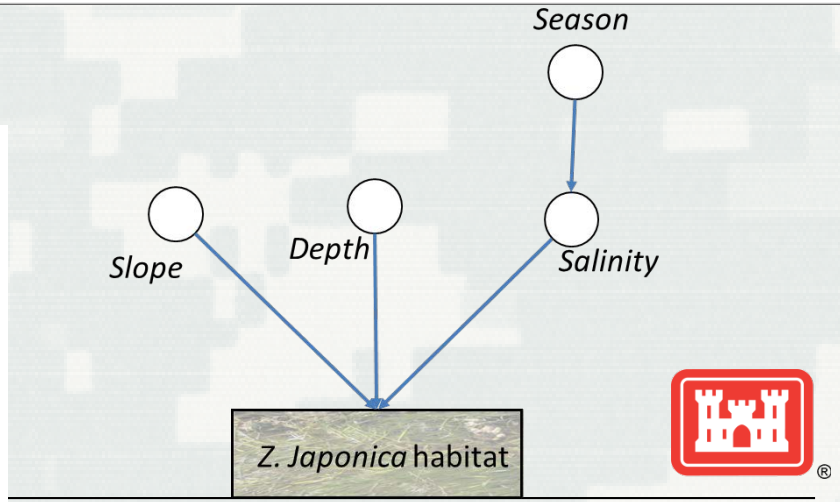
Change in Ecosystem Function

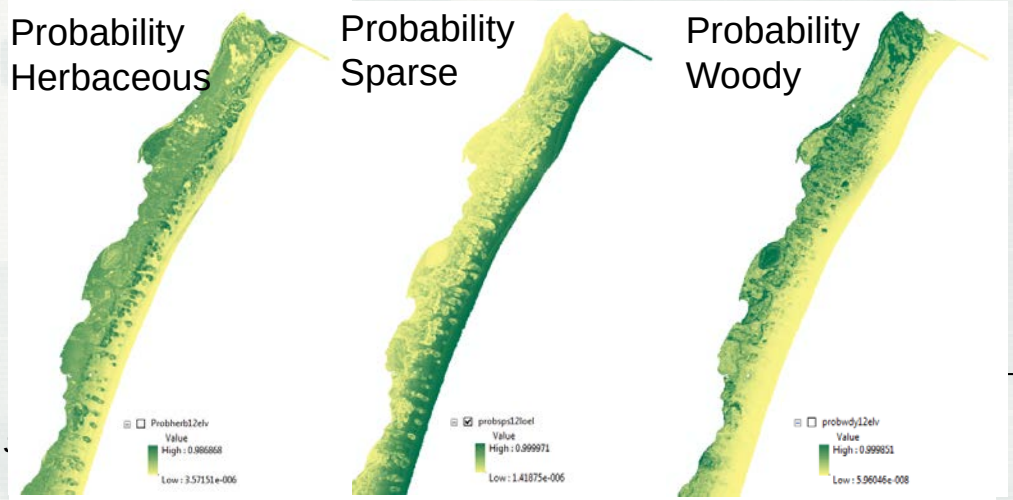
Metric	Process	Benefit
Clumpiness	Biodiversity	↑↓
Cohesion	Connectivity	↓↑

Evaluate alternative scenarios as they relate to vegetation change and describe benefits/impacts outside of habitat unit creation (i.e. how do changes tie back to ecological processes?)

Invasive Seagrass Habitat Model







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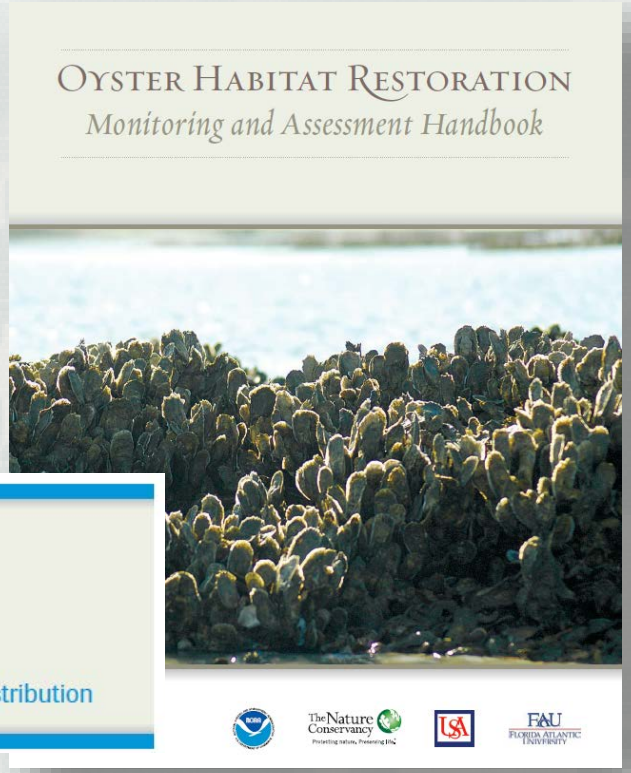
Metrics for Restoration

- Restoration Science is trending towards the concept of Universal Metrics (Baggett et al 2014)
  - Lack of monitoring data
  - Unclear restoration goals/objectives

Pros:

- Systematic Assessment of Basic Restoration Performance
- Consistent
- Comparable
- Simplified, Reduces burden
  - Role of RS has increased for rapid and remote ways to examine the effectiveness of restoration strategies



Universal Metrics

1. Reef areal dimensions
2. Reef height
3. Oyster density
4. Oyster size-frequency distribution

Monitoring Framework for Upland Hardwood and Grassland Restoration

- **Objective:**
  - To develop habitat-specific restoration monitoring frameworks that provide universal metrics for evaluating restoration performance at varying levels of precision
- **General Approach:**
  - Compilation of Monitoring Metrics
  - Tiered Precision (3 levels)
  - Traditional Field Based vs. Remote Sensing

Project Questions:

1. What are common measures and/or metrics to monitor the performance of upland hardwoods and grassland restoration projects?
2. What are the advantages/disadvantages (precision, level-of-effort, etc.) between common monitoring metrics? (traditional vs remote sensing)

Metrics for Restoration

- Using the literature, the team is developing a tiered framework with the following kinds of information:

Upland Hardwood Site

Tier One (Universal Metrics for all Hardwood Restoration)							
Metric Type	Calculated Metrics 1-Structural Metrics 2-Compositional Metrics 3-Ecosystem Service Metrics	Field Collected Data	Methodology (plot size, distribution, and number of samples will be determined by consultation with statistician)	Level of Effort (estimates for field personnel hours and/or data processing hours)	Sampling Guidelines Post implementation Timeframe (Early, Mid, Late) Frequency (estimated time between sampling events for measurable change)	Precision (determined by confidence required/desired by practitioner and restoration objectives)	Product

- Spatial measurements can be used to quantitatively assess restoration objectives in four main areas: 1) habitat extent and landscape structure, 2) habitat degradation, 3) biodiversity, and 4) threats/pressures

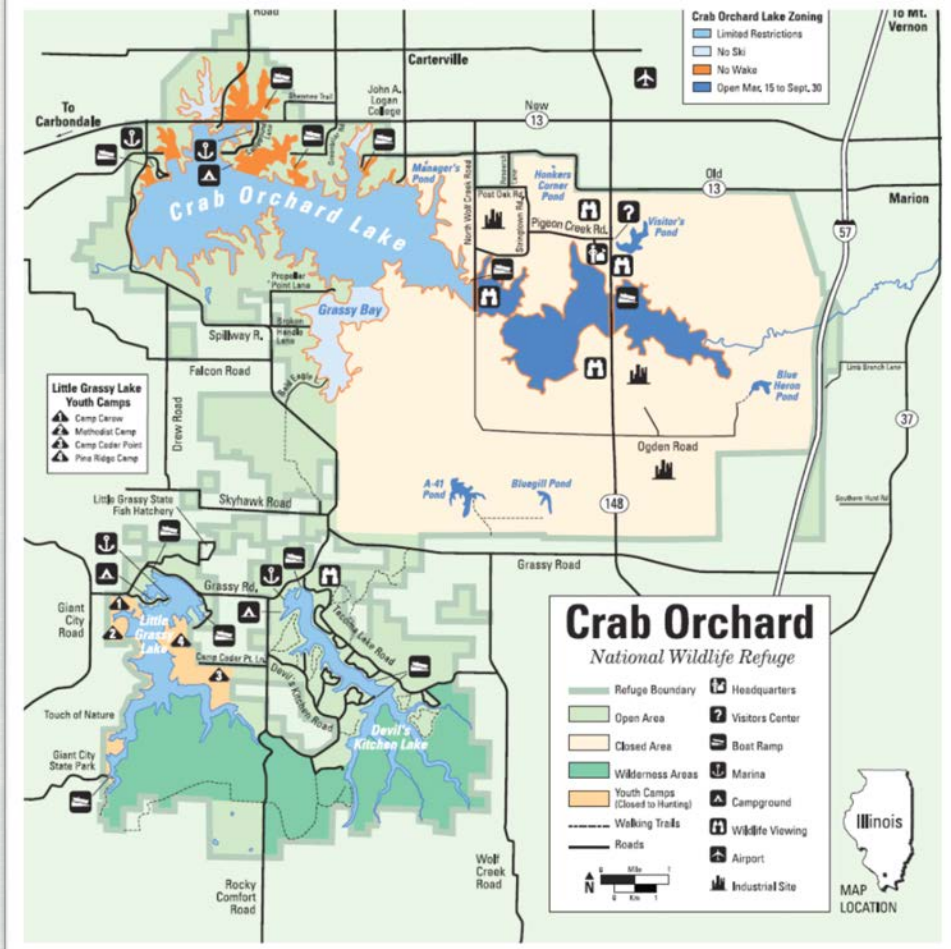
Remote Sensing for Restoration Ecology: Application for Restoring Degraded Ecosystems

(authors Reif and Theel, accepted for publication in IEAM, Fall 2016)

Platform	Sensort Type	Sensor	Spectral Bands (NM)	Spatial Resolution (M)	Swath Width	Revisit (Days)	Operator	Cost	Applications/Metric
Medium Resolution Spaceborne	Optical - Multispectral	Landsat-8	1-7, 9 (435-2294), Pan 8 (503-676), 10-11 (1060-1251)	15, 30, 100 (Pan, MS, TIR)	185 KM	16 days	USGS	Free	Broad-scale land cover or habitat type/pattern, general biodiversity/species richness, Rapid change detection or loss/gain, seasonal/multi-year changes, Overall forest extent/clearance/regeneration, Overall degradation or disturbance from fire, grazing, drought, etc, broad biophysical estimates (NDVI, NPP, LAI etc), landscape metrics (landscape and class level), such as fragmentation
Medium Resolution Spaceborne	Optical - Multispectral	Indian Remote Sensing-P5 (IRS-P6) also called Resourcesat-1 and 2	3 (520-860), 4 (520-1700), Pan (500-850)	5, 20, & 60 (Pan, MS)	70, 141 & 740 KM	5 days	Indian Space Research Organization	1700-4500 EUR/scene	
Medium Resolution Spaceborne	Optical - Multispectral	Systeme Pour l'Observation de la Terre (SPOT-7)	4 (455-890), Pan (450-745)	1.5-2.5, 6-10 (Pan, MS)	60 KM	1-5 days	Satish Dhawan Space Center	Some archives free; $32/KM	
Medium Resolution Spaceborne	Optical - Multispectral	Sentinel-2A	13 (400-2400)	10 (b2-4, 8a), 20 (b5-8b, 11, 12), 60 (b1, 9-	290 KM	10 days	ESA	availabe Oct 2015/Free	
Medium Resolution Spaceborne	Optical - Multispectral	RapidEye	5 (400-850)	6.5	77 KM	1 day	Blackbridge	0.95-1.05 EUR/KM	
Medium Resolution Spaceborne	Optical - Multispectral	TERRA ASTER	14 (520-2430)	15 (VNIR), 30 (SWIR), 90 (TIR)	60 KM	16 days	NASA RSE		
High Resolution Spaceborne	Optical - Multispectral	Worldview-3	8 MS (400-1040), 8 SWIR (1195-2365), Pan (450-800)	0.31, 1.24 (Pan, MS)	13.1 KM	1-4 days	DigitalGlobe	$18-40/KM	Fine-scale land cover, habitat type/pattern, some species mapping (homogenous areas), composition/abundance/distribution (homogenous areas), indicators of biodiversity/species richness (homogenous areas), detailed degradation or disturbance (some invasive species, pest attacks, fire, grazing, etc), individual feature delineation (e.g. tree crowns), more detailed biophysical estimates (NDVI, NPP, LAI, etc) such as with WV-2 and-3 (higher spectral resolution), and landscape metrics (landscape, class, and patch level)
High Resolution Spaceborne	Optical - Multispectral	Worldview-2	8 (400-1040), Pan (450-800)	0.31, 1.84 (Pan, MS)	16.4 KM	2-8 days	DigitalGlobe	$18-40/KM	
High Resolution Spaceborne	Optical - Multispectral	GeoEye-1	4 (450-920), Pan (450-900)	0.41, 1.64 (Pan, MS)	15.2 KM	2-11 days	DigitalGlobe	$14-28/KM	
High Resolution Spaceborne	Optical - Multispectral	OrbView-3	4 (450-900), Pan (450-900)	1, 4 (Pan, MS)	8 KM	2-11 days	DigitalGlobe		
High Resolution Spaceborne	Optical - Multispectral	IKONOS-2	4(450-860), Pan (450-900)	1, 4 (Pan, MS)	11.3 KM	2-11 days	DigitalGlobe	$10/KM	
High Resolution Spaceborne	Optical - Multispectral	Quickbird-2	4(450-900), Pan (450-900)	0.6, 2.4 (Pan, MS)	16.5 KM	2-12 days	DigitalGlobe	$14-28/KM	
High Resolution Airborne	Optical - Multispectral	Special Project Contract	3- or 4-bands	~0.5 or as specified	varies with altitude	Once	Vendor specific		
High Resolution Airborne	Optical - Multispectral	Programmatic (NAIP, NCMP)	Varies (3-and 4-bands)	Varies (~0.3 - 1)	varies with altitude	depends on program	Program specific	Free	
High Resolution Spaceborne	Optical - Hyperspectral	Hyperion	220 (400 - 2500)	30	7.5 KM	30 days	NASA		Detailed vegetation species discrimination (spectrally similar), detailed biophysical estimates and stress based on chemical composition, nutrient deficiency, etc, spectral heterogeneity related to species richness/diversity, detailed disturbance and degradation (invasive species, changes in foliage, biomass etc)
High Resolution Spaceborne	Optical - Hyperspectral	CHRIS	63 (400-1050)	36	13 KM	?	ESA		
High Resolution Airborne	Optical - Hyperspectral	CASI-1500	Programmable, up to 288 bands (380-1050)	Varies with altitude (~0.2-2)	varies with altitude	Once	ITRES		
High Resolution Airborne	Optical - Hyperspectral	HyMap	450-2480)	3.5-10	varies with altitude	Once	HyVista		
High Resolution Spaceborne	Active - Radar	RADARSAT-2 (SAR)	C-band	3-100	varies (20 - 500 KM)	3 days	MDA (Kanada)		Detailed vegetation structure, biomass, and height characteristics, combined with imagery for improved species identification, assist with biophysical estimates, detailed 3-D, height, LAI, biomass, age, succession, and composition
High Resolution Spaceborne	Active - Radar	TerraSAR-X/TanDEM	X-band	1-16	varies (10 - 100 KM)	<3 days	EADS Astrium, DLR		
High Resolution Airborne	Active - Lidar	Vendor specific	1064 or 532 (terrestrial or bathymetric	spot spacing varies	varies with altitude	Once	Vendor specific		

Survey Site

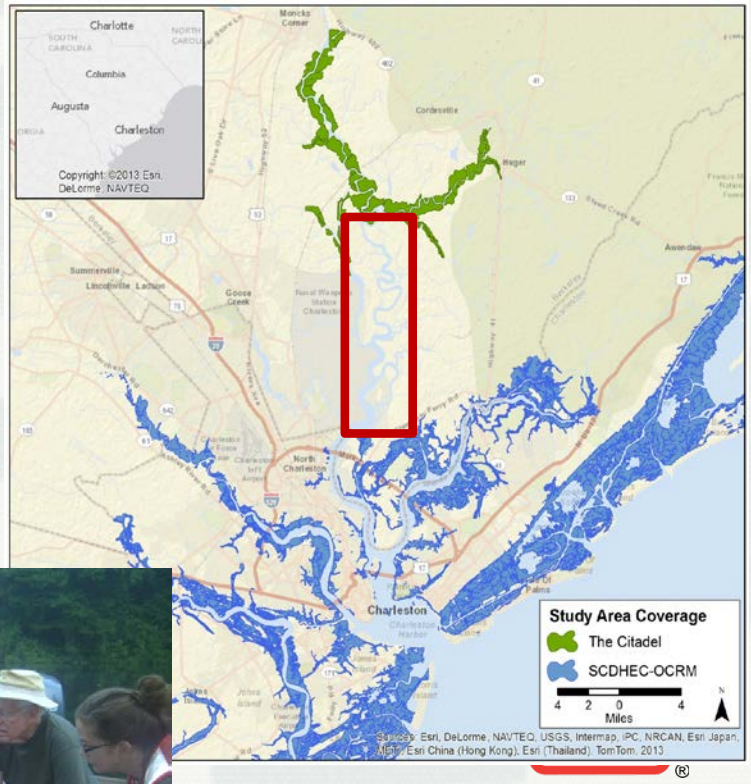
- Crab Orchard NWR, IL
  - 43,890 ac
  - 4 primary purposes: Wildlife Conservation, Agriculture, Industry, and Recreation
- For each habitat type, 4 sites for each 'treatment':
  - Primary Restoration (NRDA contaminated sites)
  - Compensatory Restoration (ag prior land use)
  - Reference
- Use similar size sites (~ avg site size +/- 1 SD)
- At least 5 plots per site, plus RS ground truth
- Execute each tier (1-3) at each plot to characterize site



	Forest	Grassland
Total # CONWR Sites	204	18
Restoration Implementation Completed	102	15
# Primary Restoration	17	4
# Compensatory Restoration	85	11
Mean Area (Confirmed Planted)	9.6	29.4
Min. Area	0.6	2.5
Max. Area	54.5	112.1
Standard Deviation	10.5	27.9

Wetland Habitat Mapping (rewind to 2014 workshop)

- Charleston Harbor Post 45 feasibility study analyzed and evaluated improvements to the harbor/channel
  - Assess potential project impacts to surrounding wetlands as a result of deepening
  - Impact assessment required updated wetland characterization near the harbor as a baseline
  - Wetland maps were used with the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model to quantify potential wetland impacts as a result of project alternatives
  - Salinity is the primary variable affecting conversion
  - Use existing WorldView-2 imagery

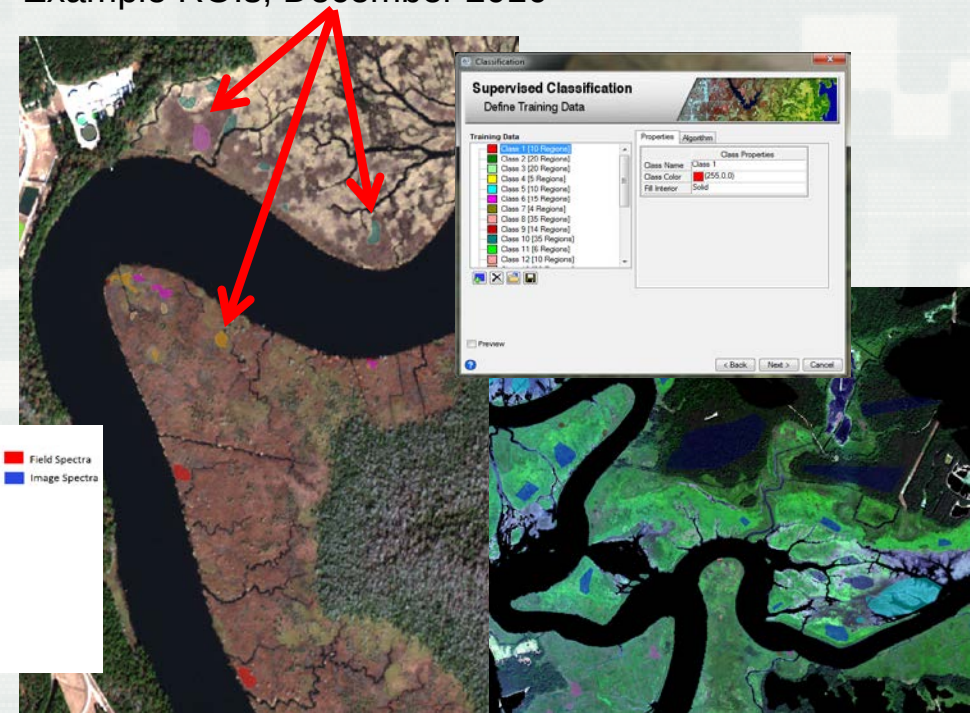


Field Work and Image Classification

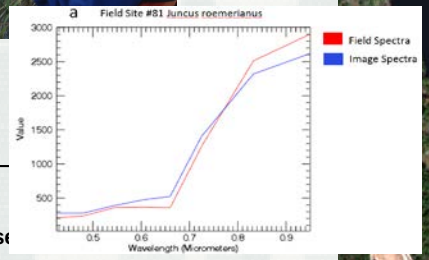
- Two field surveys conducted in December 2012 and June 2013
  - Collected for training and validation
    - lat/long (Trimble GeoXH 6000)
    - dominant wetland plant species determined by local plant specialist
    - spectral reflectance of the dominant plant species (ASD FieldSpec HH2), and
    - GPS tagged photographs (Ricoh 500se camera)

- Maximum Likelihood classifier; calculates the probability that a given pixel belongs to a class
- Multi-temporal scenes used to assist with discriminating veg types
- Sometimes multiple classes identified to represent one wetland type due to within-class spectral variability

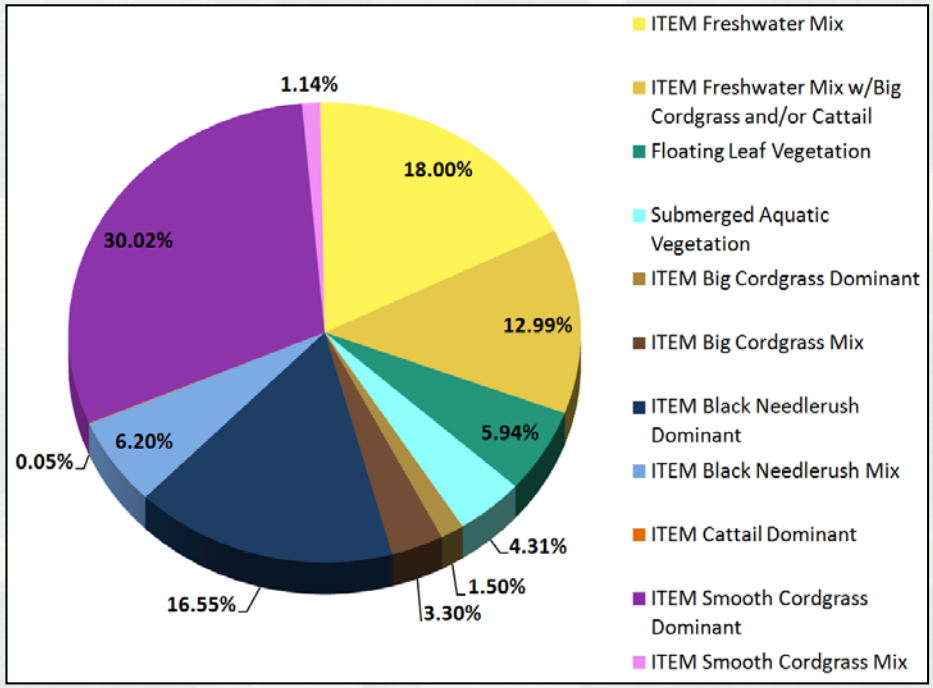
Example ROIs, December 2010



FYI – don't drop this in the water…

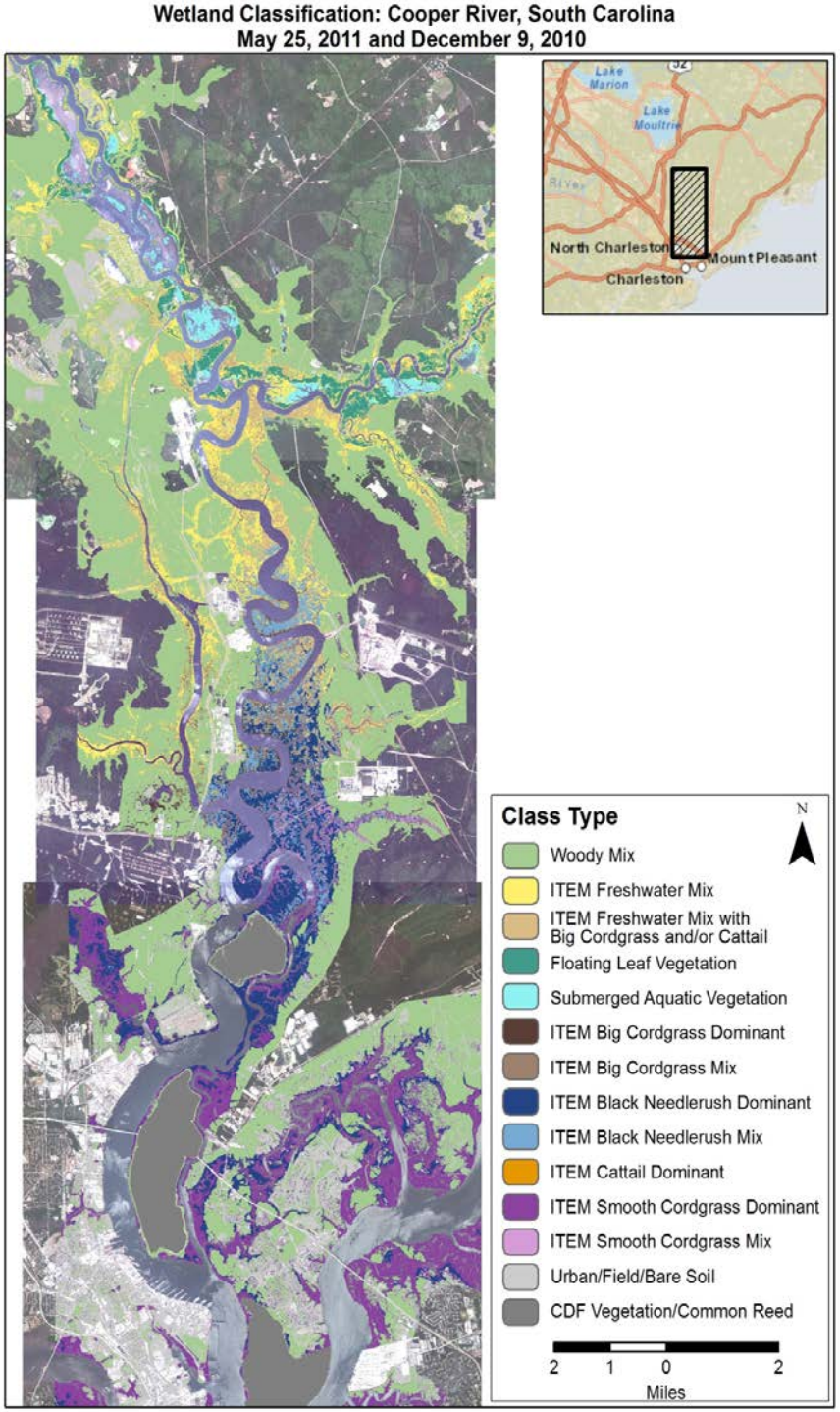


Results



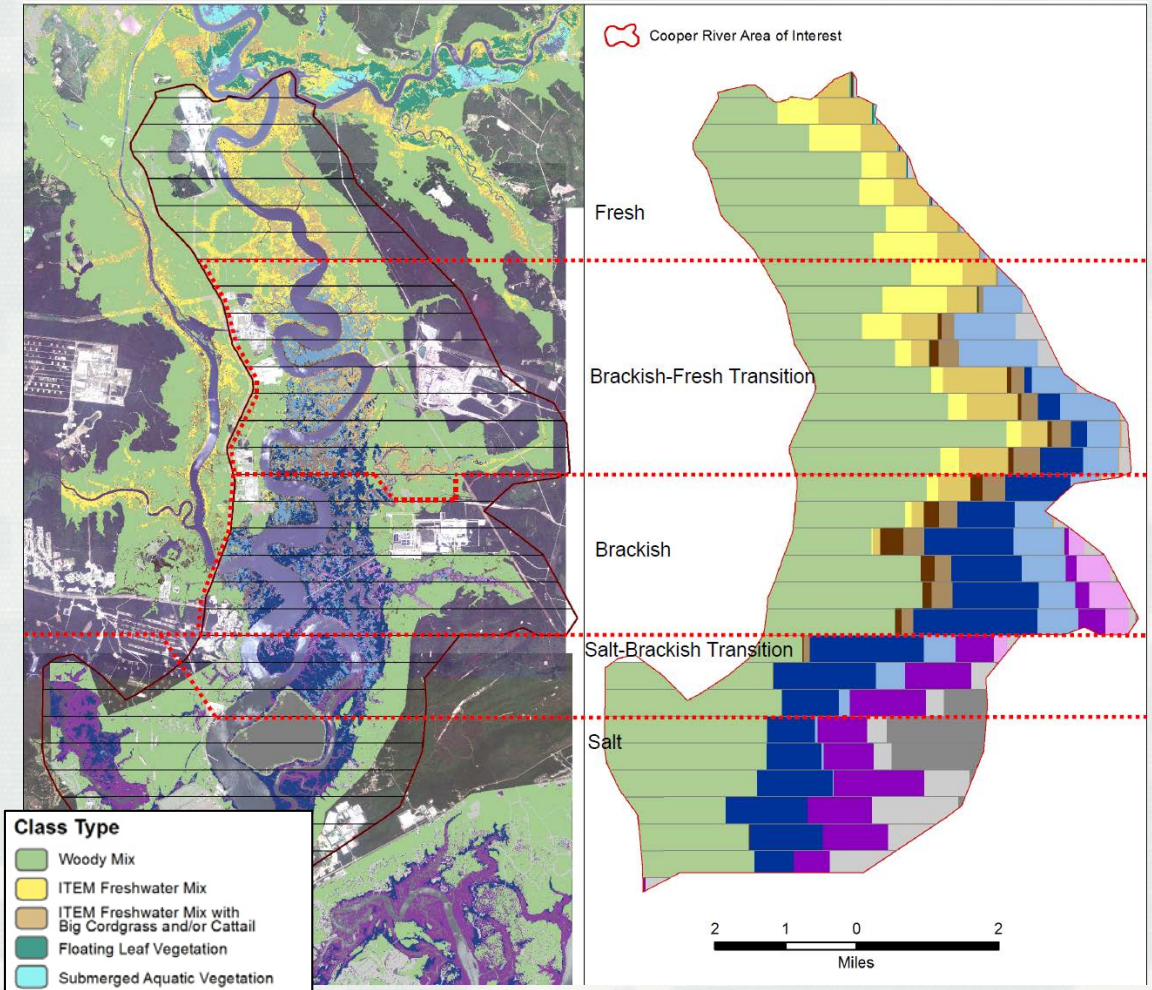
Area distribution of wetland classes, excluding Woody Mix

Overall accuracy 81.25%



Wetland Impact Assessment

- Depict transition zones between freshwater, brackish and saltwater marshes:
  - 2,000-ft blocks delineated for area of interest
  - In each block, the % area of each class type was calculated
- Transect analysis helps establish break points between assessment reaches (red dashed line)
- Data used to determine % freshwater vs. saltwater vegetation within assessment reaches

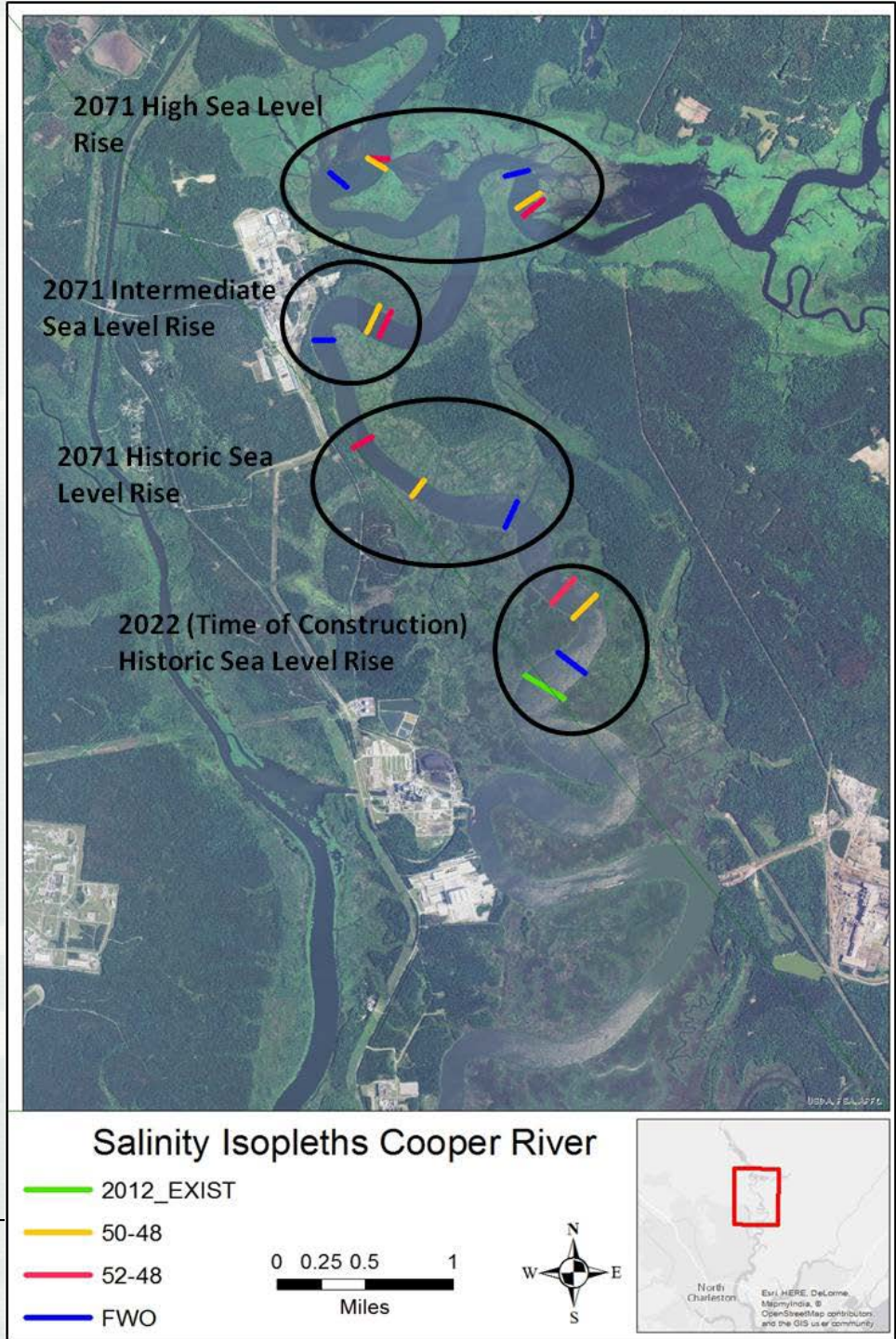


Class Type

- 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

Wetland Impact

1. Determine length of river and wetlands per river foot in assessment reaches
2. Determine habitat coverage associated with assessment reaches
3. Determine salinity isopleths
   - Focused on the movement of the 0.5 ppt contour
   - Project-induced salinity movement varied based on sea level scenarios



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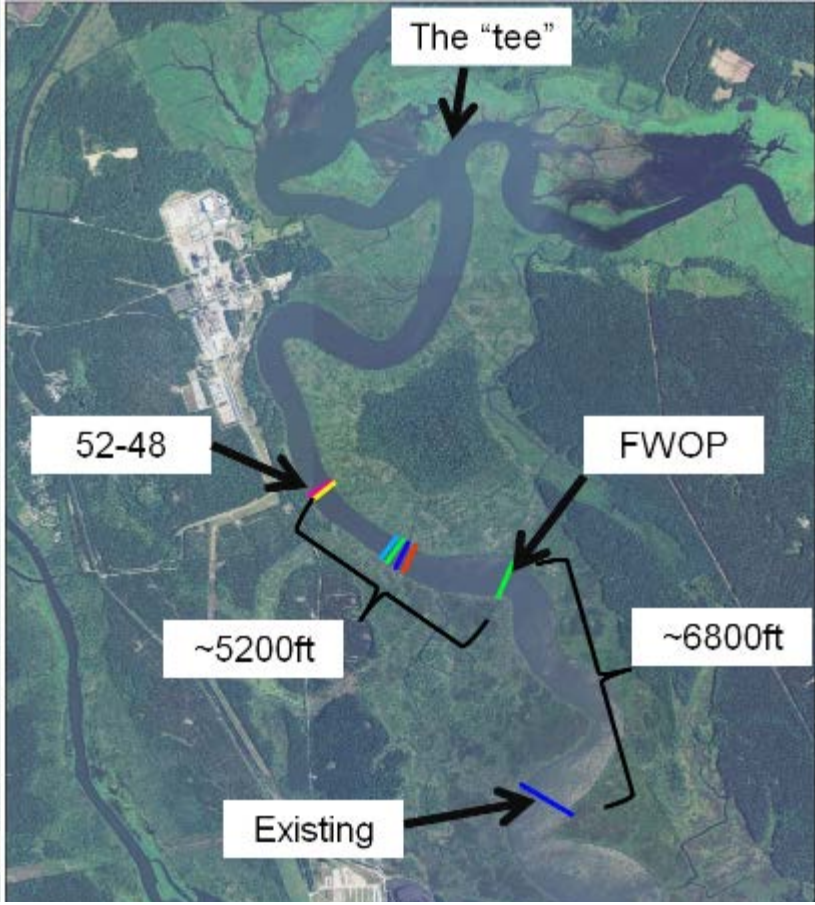
4. Measure isopleth shift distance in feet between FWOP and each with project condition

5. Calculate wetland acres affected by alternatives
   - River-feet of isopleth movement X wetlands/river-foot
   - Evaluated varying sea level rise scenarios and averaged results



	Average Wetland Impacts (All Four Scenarios)	
Wetland Impacts	50/48	52/48
Ashley River forested wetlands	3.52 acres	4.36 acres
Ashley River marsh wetlands	10.86 acres	13.16 acres
Cooper River forested wetlands	89.65 acres	126.37 acres
Cooper River marsh wetlands	127.57 acres	179.83 acres
Total	231.60 acres	323.72 acres

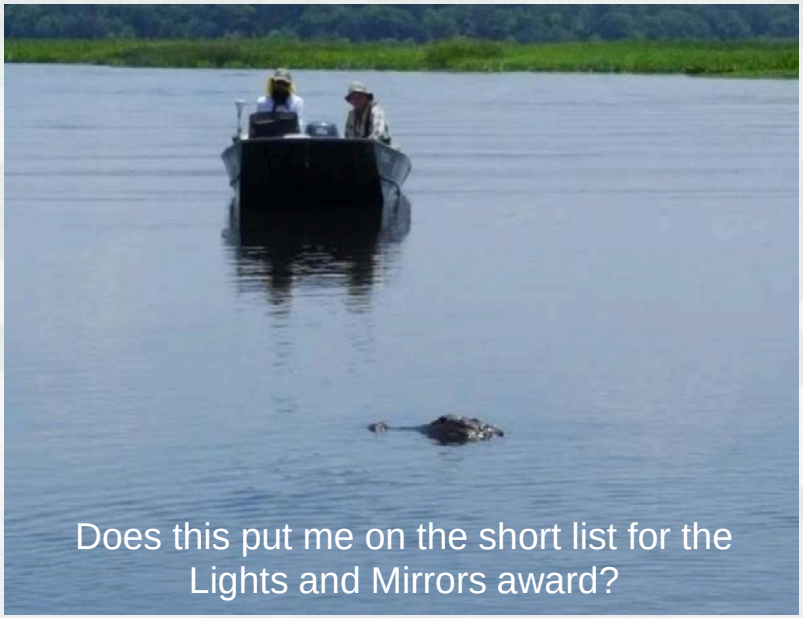
Mitigation and Future Work

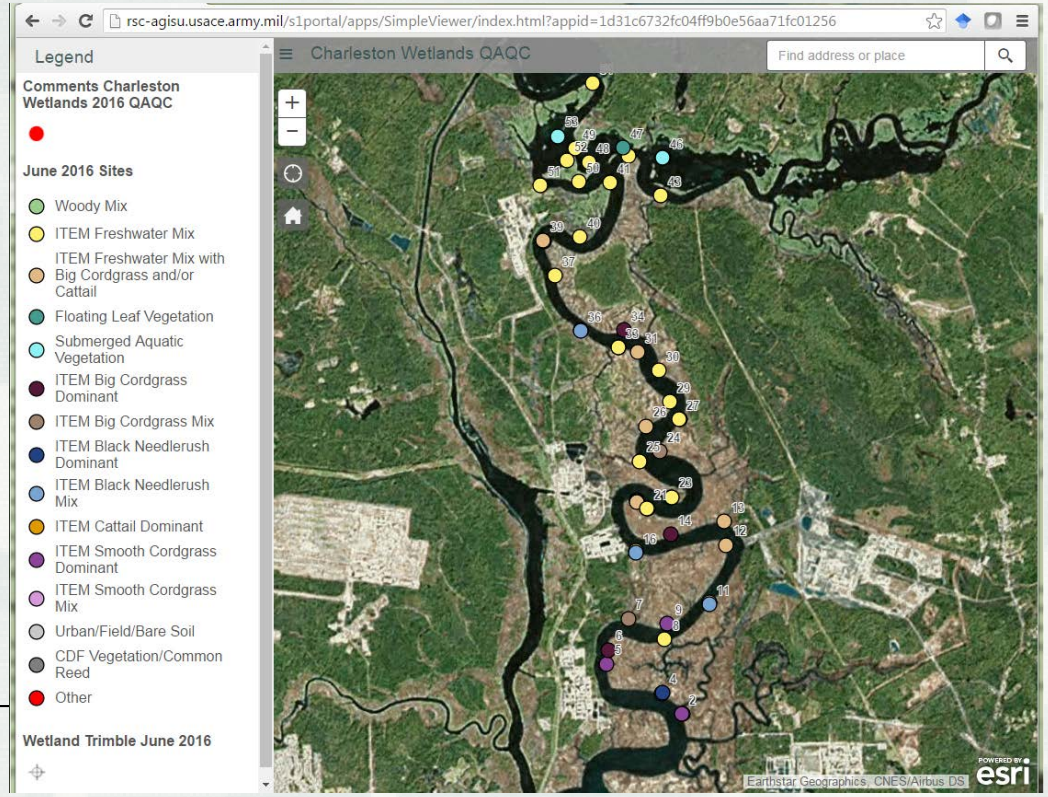
- Project-induced salinity movement upriver
- Salinity impacts to ~324 acres of freshwater wetland habitat; about 20% increase in saltwater vegetation in upper reaches
- Used to determine mitigation (preservation of 665 acres of wetlands)
- As part of its monitoring and adaptive management plan, the Corps will use the same remote sensing approach and new imagery to re-evaluate the area prior to construction and at post-construction (+1, +3, and +5) years to monitor potential project impacts

FY16-17

- Early summer & winter 2016 field work corresponding with WV-3 image requests to update maps prior to construction in FY17-18
- Map updates will be used to evaluate inter-annual variability and potential changes in wetland habitats as a function of salinity changes

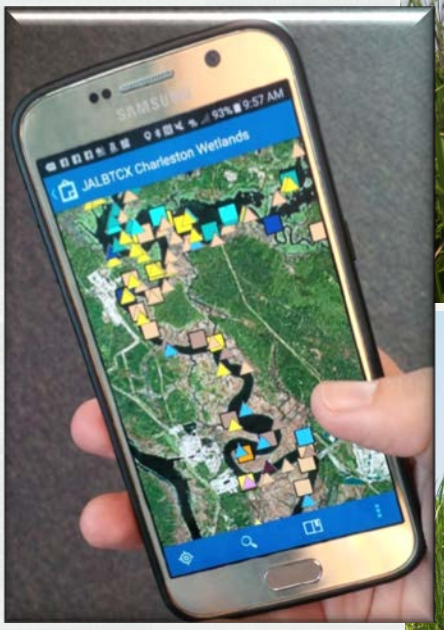
June 2016: 55 new field sites



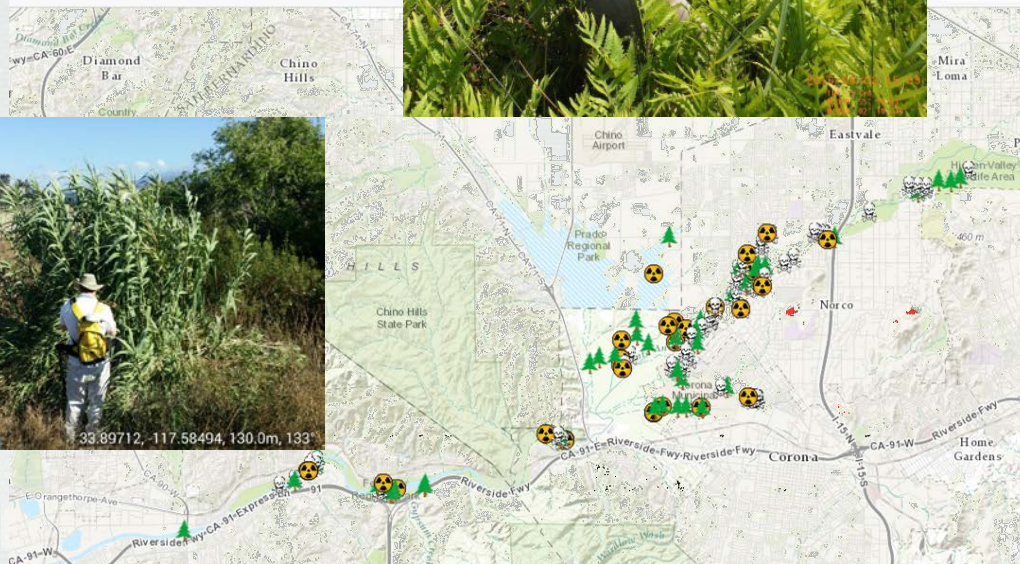


ArcGIS Collector App

- Use smartphone to collect field data
  1. Create and publish/share a map using ArcGIS Online or Portal for ArcGIS (**requires ArcGIS organizational account**)
  2. Create an editable feature layer (e.g., point file to add sites to) and configure attributes (e.g., preset drop-down list)
  3. Download and sign in to App on your phone to see and collect data (e.g., add points, attach photos)
  4. Work offline by downloading the map to your device; sync later once reconnected
  - *Adjust GPS accuracy in settings*
  - *Use USB battery pack*



Not looking for Pokemon thingys!



Questions?