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Mapping Underwater Benthic Habitats From ADS40 Digital Airborne Imagery Using Semi-Automated Methods

JACIE Civil Commercial Imagery Evaluation Workshop 2007

Fairfax, VA

Collaboration

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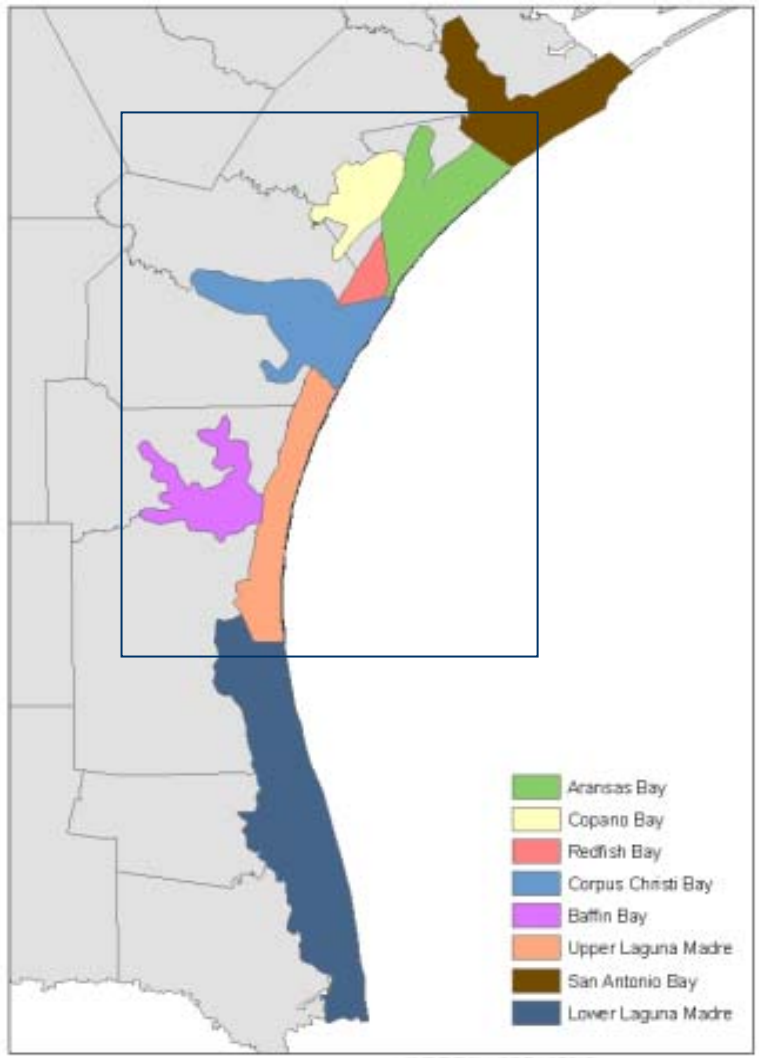
- Bill Stevenson, PSGC at NOAA CSC
- John Wood, Harte Research Institute at Texas A&M University--Corpus Christi
- Jim Simons, Coastal Fisheries Division, Texas Parks and Wildlife
- Harold Rempel, Anne Miglarese, EarthData International

Project Goal

- To develop a detailed and accurate benthic habitat map of the southern portion of the Texas coast
- Use high resolution digital aerial imagery
- Use semi-automated methods to delineate habitats and label them
- Map will support Texas Seagrass Monitoring Plan

Project Area- Texas Coastal Bend

- 6 Bay systems for phase 1
- ~1400 miles^2 or 3625 km^2
- Mapping inside barrier island system



Source Imagery

- 2004 NAIP imagery
- 1m ADS40 digital airborne imagery, resampled to 2m
- Reprocessed true color and CIR

What are we mapping?

- Underwater habitats as well as several ‘land’ habitats
- Our classification scheme derived from the Florida System for Classification of Estuarine and Marine Environments (SCHEME)
  - Hierarchical
  - Mutually exclusive
  - Completely exhaustive
  - Dynamic
  - Includes descriptive modifiers
- Minimum Mapping Unit 100 m^2

Our Classes

- Benthic Habitats
  - Continuous SRV (Seagrass)
  - Patchy SRV
  - Continuous Macroalgae*****
  - Patchy Macroalgae*****
  - Oysters
  - Unconsolidated Sediments
  - Hardbottom
  - Unknown Habitat
- Land/Land Interface Habitats
  - Land
  - *Spartina*
  - Mangroves

*****Macroalgae classes are no longer mapped classes -- Macroalgae is only used as a modifier now*****

Classification Scheme Rules

If habitat is falls within the “land” boundary as identified either by image classification or ancillary data then

-If landcover consists of greater than or equal to 50% oysters, then **Bivalve Reef (321)**
-Else if landcover is greater than or equal to 50% mangrove tree canopy, then **Tidal Swamp-Mangroves (5)**
-Else if landcover is greater than or equal to 50% *Spartina*, then **Tidal Marsh – *Spartina* (4)**
-Else **Land (6)**
-Else benthic habitat

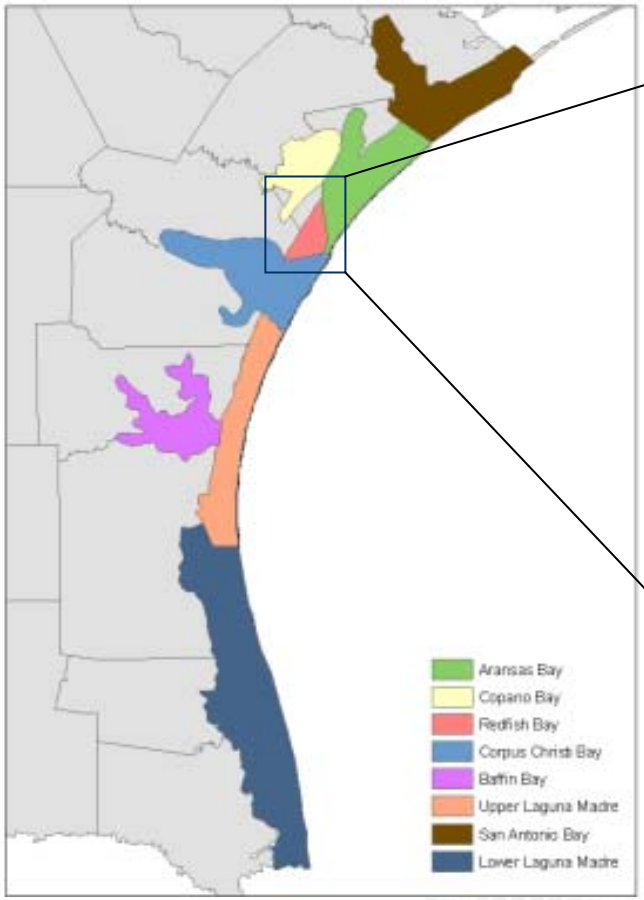
If interpretation of benthic habitat is not possible because of water quality or water depth, then **Unknown Benthic Habitat (7)**

If Submerged Aquatic Vegetation (SAV) cover is greater than 10%, and reef/hardbottom cover is less than SAV cover then SAV (2)

Project Methods

- Collect ancillary data
- Reprocess NAIP imagery to NOAA specs
- Pilot project in Redfish Bay to determine classification methodology
- Collect field data, correlate landscape variability with spectral variability
  - Create 1st map
- Accuracy assessment, map review
- Collect more field data to resolve map confusion and errors
- Edit map
- Final accuracy assessment, map review
- Per-pixel classification of Seagrass and Non-Seagrass pixels within Patchy Seagrass polygons

Pilot Project-Redfish Bay



Pilot Project-Redfish Bay

- Tested four methods
  - Visual Learning Systems Feature Analyst Unsupervised Classification to delineate habitats, labeling of habitat polygons by CART analysis
  - Feature Analyst Wall-to-Wall Classification
  - Feature Analyst traditional Feature-by-Feature Extraction-performed by VLS
  - Definiens Professional to delineate habitats, labeling of habitat polygons by CART analysis
- Identical imagery, training sites, accuracy sites used and no editing performed

Classification And Regression Tree (CART) Analysis

- A statistical analysis that predicts variables (class) from multiple continuous and/or categorical variables
- “Mines” your independent variables and builds a hierarchical tree diagram (set of “if-then” statements) to predict the your dependent variables
- CART is powerful:
  - Can accept both continuous and categorical data
  - Results are easy to interpret
  - No assumptions about data distributions
  - Can find complex relationships between variables
  - Does not require statistical expertise to use

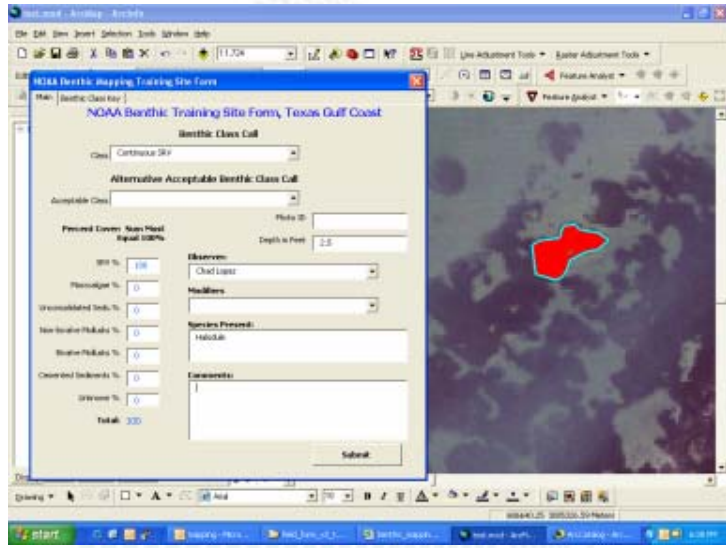
Pilot Project Conclusions

- All methods had very similar accuracy assessment results
- Feature Analyst Wall-to-Wall and labeling by CART much less time consuming
- Could not get reliable habitat delineations with Feature Analyst
- Definiens Professional produced much more reliable delineations
  - tradeoff of detailed polygons is that it produces so many

Method chosen for project: **Create habitat polygons using Definiens Professional and label polygons using CART analysis**

Calibration Field Trip

- 4 weeks in the field-summer 2006
- Field Equipment
  - Laptop with all data loaded
  - GPS with field points loaded
  - Underwater video
  - Underwater digital camera
  - Hardcopy maps of imagery
  - Hardcopy field forms
- Collected 583 field sites
- 50 sites per class randomly selected and set aside for accuracy assessment
- Remaining used as signature calibration sites for mapping



Temporal Difference Between Image Collection and Field Site Collection Dates

- 1.5 Year difference
  - Image collection November 2004
  - First field data collection May 2006
- Must map to imagery, not to current field conditions
  - Challenging due to dynamic environment
- Must be able to gain enough knowledge of image signatures and field conditions to infer what field conditions were then vs. what they are now

Classification of Initial Map - 1st Step

- Imagery broken into 6 processing areas
- Definiens Professional segmentation to produce polygons for each area -- over 2.6 million polygons created
- Each polygon tagged with data as attribute
  - ADS40 band means and S.D.
  - 2002 Landsat band means and S.D.
  - Majority value for ancillary vector data
    - e.g. 1990's seagrass map, NWI, NLCD
  - Bathymetry data
  - Polygon shape calculation
- Training polygon data used for CART
  - See5 statistical software used
  - CART classification rules used to label every polygon in each area
- Ran accuracy assessment for initial map from CART analysis (no editing done)

Accuracy Error Matrix for Initial Map

		Reference Data									
		Algae	SRV	Land	Mangroves	Oysters	Sediments	Unknown	Spartina	TOTALS	User's Accuracies
Classified Data	Algae	**53**	5	0	0	1	6	0	0	65	0.82
	SRV	18	**68**	3	0	20	40	11	4	164	0.41
	Land	1	0	**89**	6	1	3	0	6	106	0.84
	Mangroves	0	0	0	**88**	0	0	0	0	88	1.00
	Oysters	2	9	1	0	**80**	11	4	0	107	0.75
	Sediments	0	9	1	0	1	**27**	2	0	40	0.68
	Unknown	1	5	0	0	3	7	**83**	1	100	0.83
	Spartina	0	4	6	6	4	6	0	**89**	115	0.77
	TOTALS	75	100	100	100	110	100	100	100	785	
	Producer's Accuracies	0.71	0.68	0.89	0.88	0.73	0.27	0.83	0.89		**Overall Accuracy 0.74**

- Use error matrix to guide label editing and validation field trip data collection
- CART with boosting
  - Boosting increased overall accuracy ~10-12% vs. a single CART run

Classification of Initial Map-2nd Step

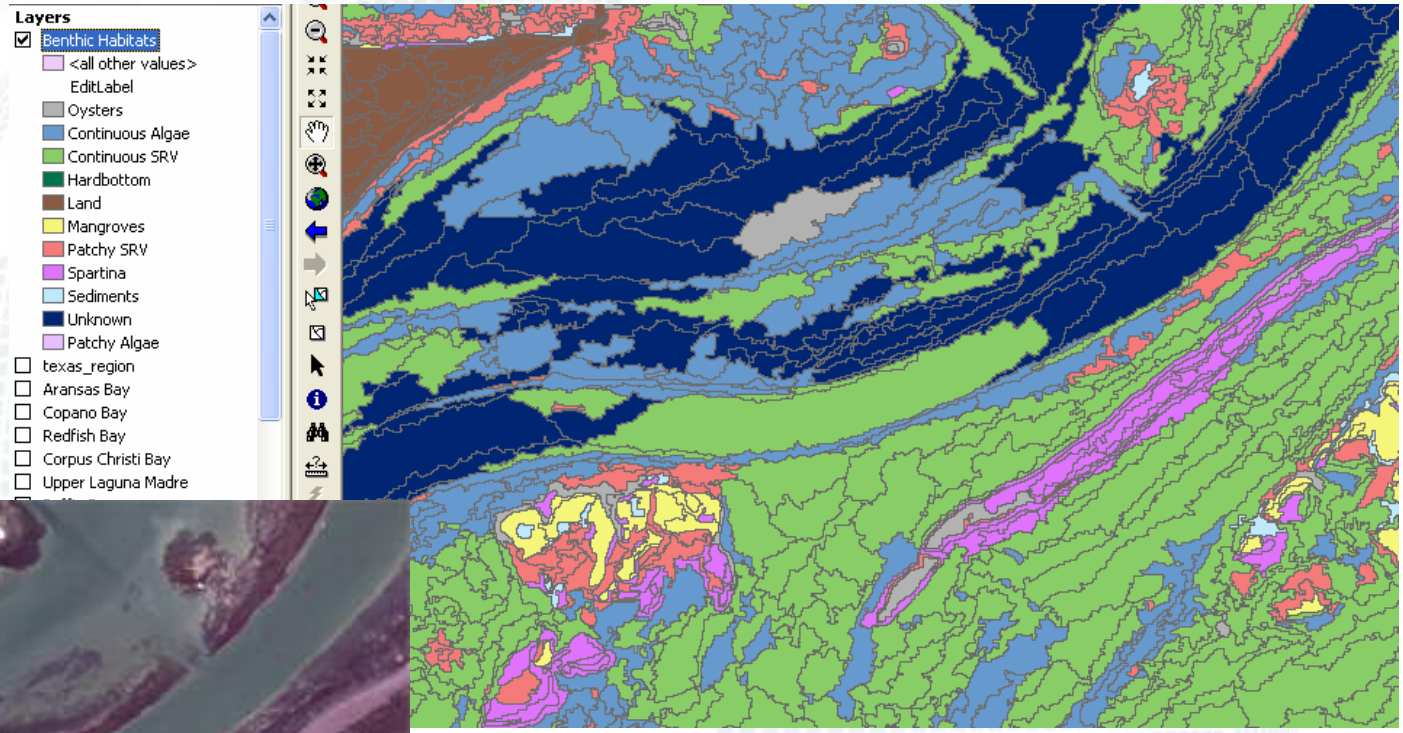
- Dissolved boundaries for known “Land” polygons and deep water “Unknown Benthic Habitat” polygons to decrease files sizes
  - Total polygons decreased from 2.6 million to < 1 million
- Edit polygon labels based on field data (not accuracy sites!), knowledge of project area, and knowledge of signature and class variability
- Focus editing on most confused classes
  - Macroalgae and Seagrass
  - Unconsolidated Sediments and Seagrass
  - Oyster Reefs and Seagrass
- Overall accuracy increase to > 80%, individual class accuracies all increased as well
- Review of initial map by NOAA and Texas partners

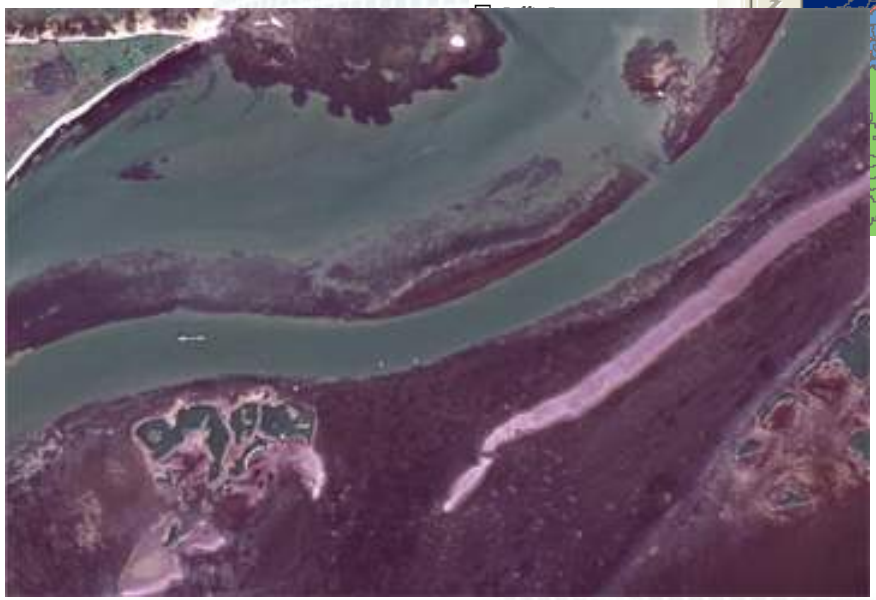
Validation Field Trip

- Field sites chosen based on
  - Class confusion identified in error matrix
  - Areas in initial map that look highly confused
  - Areas where we lacked field data from previous calibration trip
  - Comments on specific sites by NOAA and Texas partners
- 2 week trip January 22 – February 2, 2007
  - Only out in field for 6 days due to inclement weather
- Collected 213 points, plus additional 74 accuracy assessment points

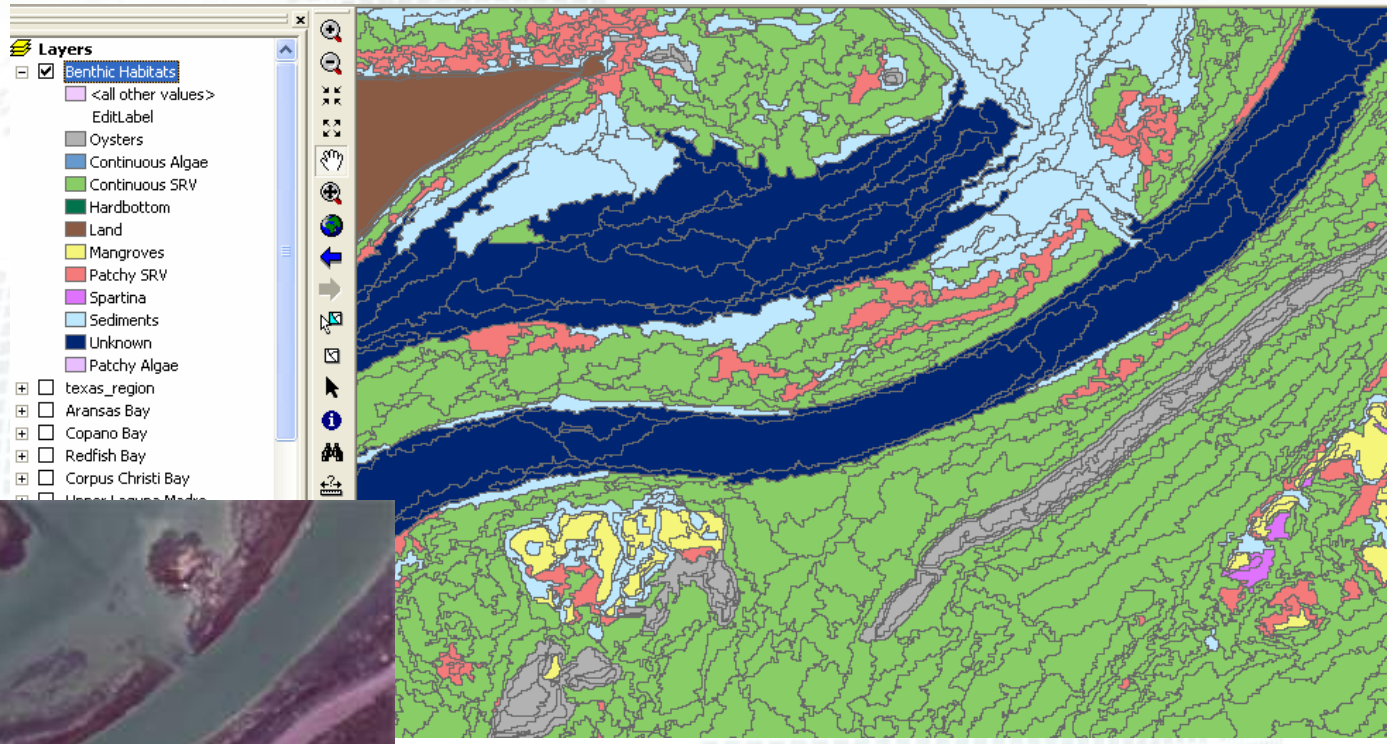
Where We Are Now

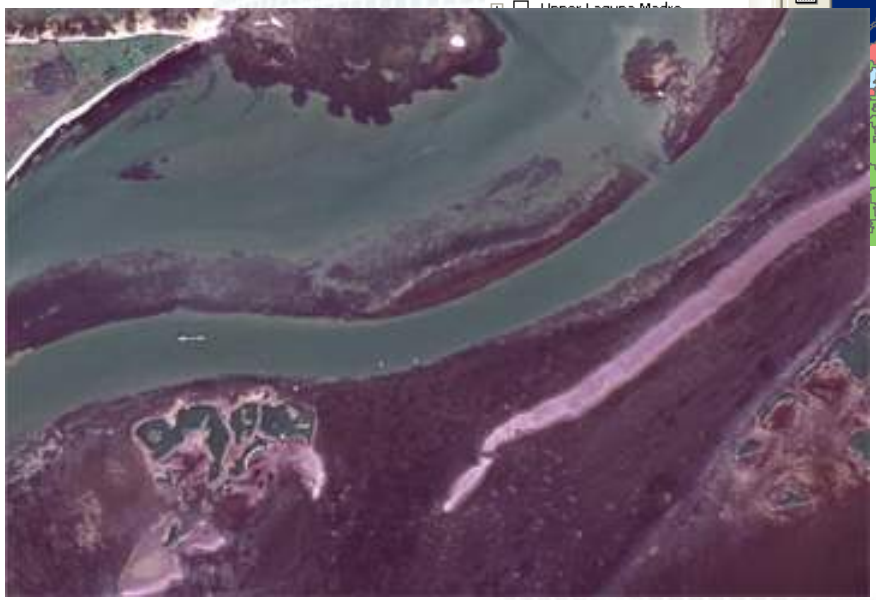
- In process of final label editing and modeling
- Recently dropped Macroalgae classes and will only use as a modifier
  - Macroalgae we have observed in field is drift algae
  - Classifying a polygon as Macroalgae is not actually representative of benthic habitat -- it's much more informative as a modifier



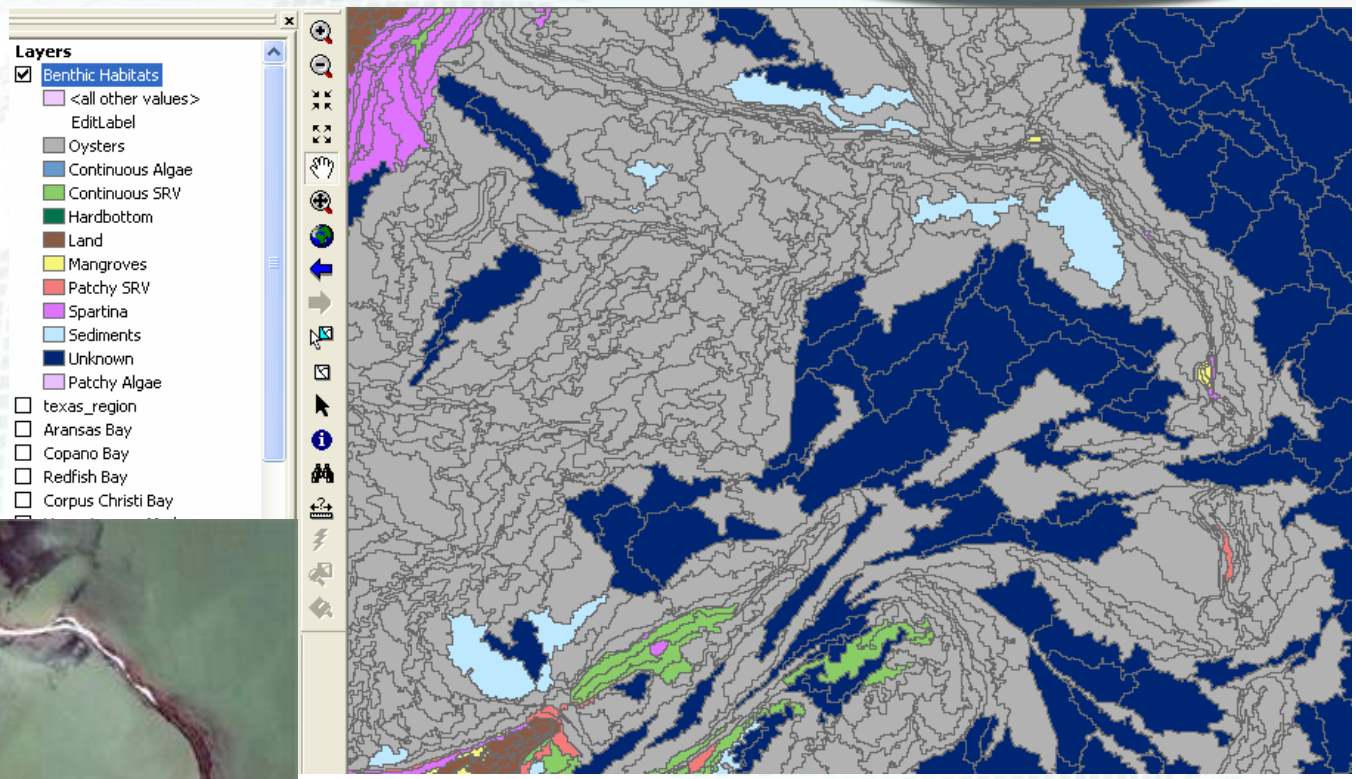


CART Labeled Map- Redfish Bay

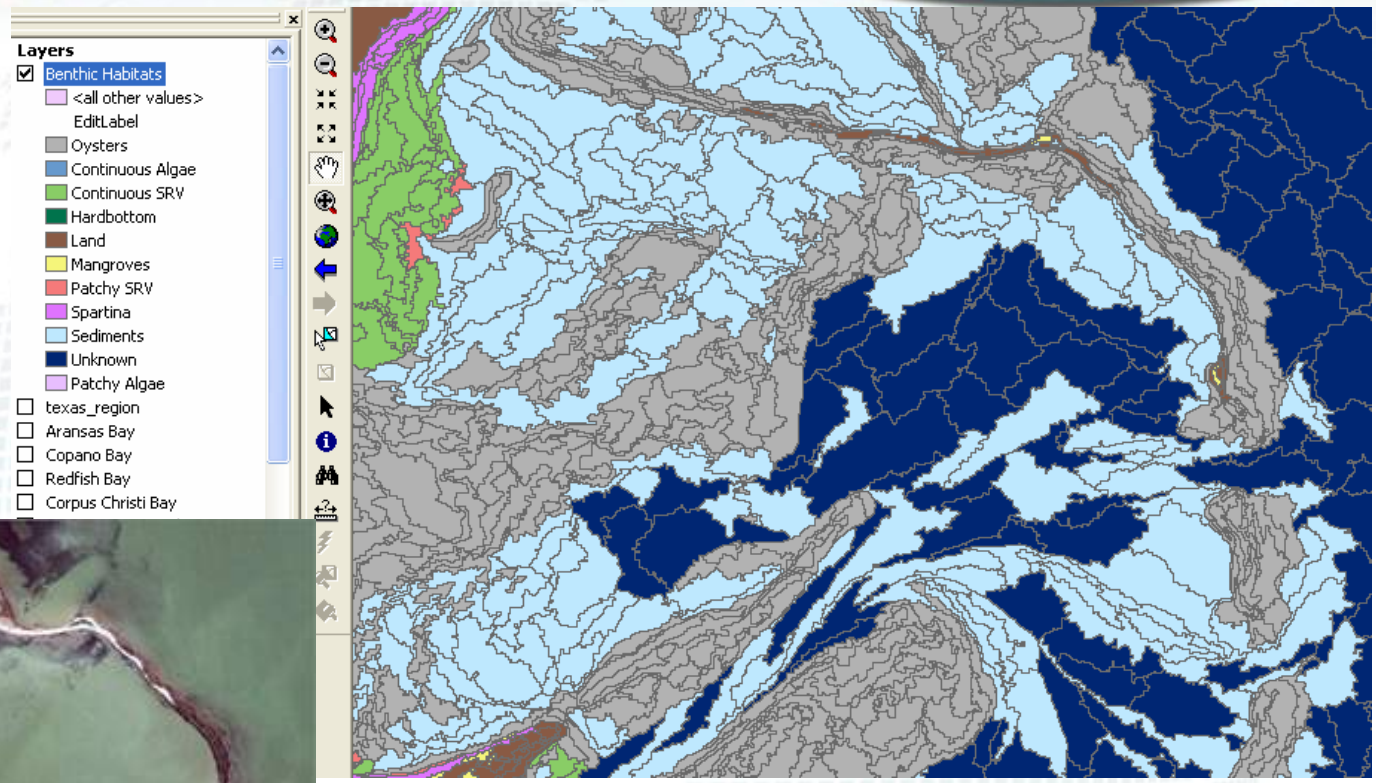




Edited Map- Redfish Bay



CART Labeled Map- Aransas Bay



Edited Map- Aransas Bay

Next Steps

- Dissolve polygon boundaries for same-class polygons that are adjacent
- Smooth polygon boundaries to remove “stair-step” effect
- Final accuracy assessment, Draft map review
- Per-pixel classification of Patchy Seagrass
  - Patchy Seagrass polygons used to mask imagery
  - Binary classification of pixels within polygon
    - Seagrass or Non-Seagrass
    - Erdas Imagine supervised or unsupervised classification
  - Two resulting products
    - Raster map of Seagrass/Non-Seagrass pixels
    - Shapefile of Patchy Seagrass polygons with % seagrass cover as attribute calculated using raster map

Lessons Learned-Improvements for Phase 2

- Divide project area into Land and Water
  - Run separate CART analyses for Land and Water classes
- Divide CART inputs into even more “unique” training sites
- Run separate CART analyses for different regions
  - e.g. Oysters might be present in one region but not another
- Create “nested” polygons

The End

Upper Laguna Madre, photo by Dan Bubser