Improving an Object-Oriented Methodology for Mapping Texas Benthic Habitats

NOAA Coastal GeoTools 2009

Myrtle Beach, SC

Collaboration

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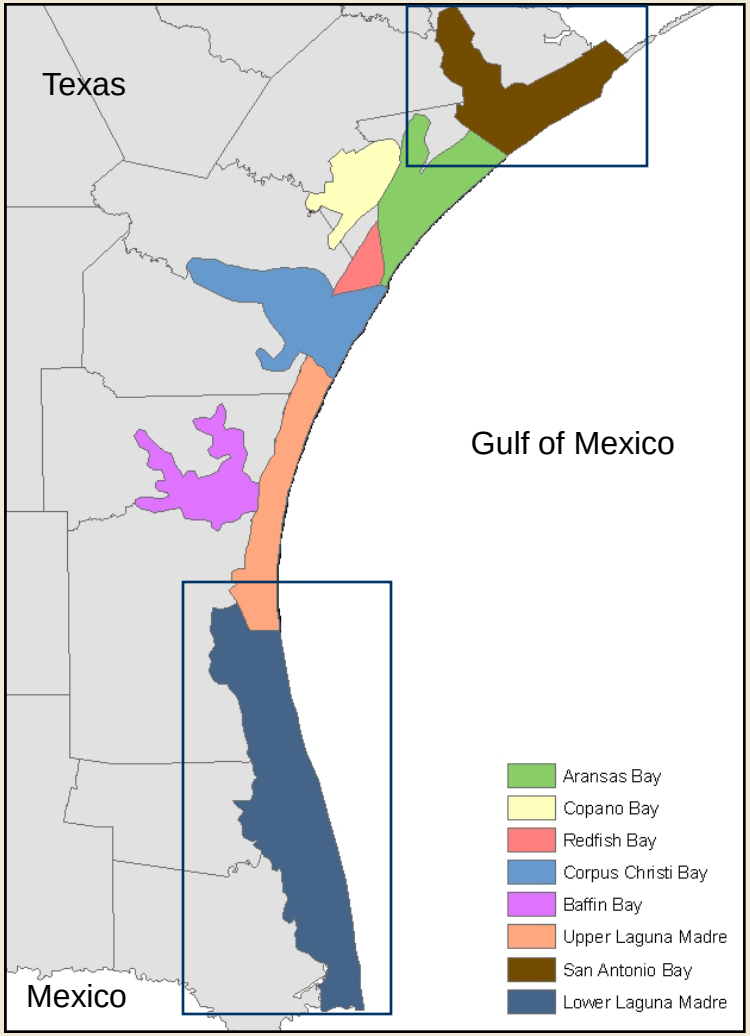
- Jim Simons, Coastal Fisheries Division, Texas Parks and Wildlife

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

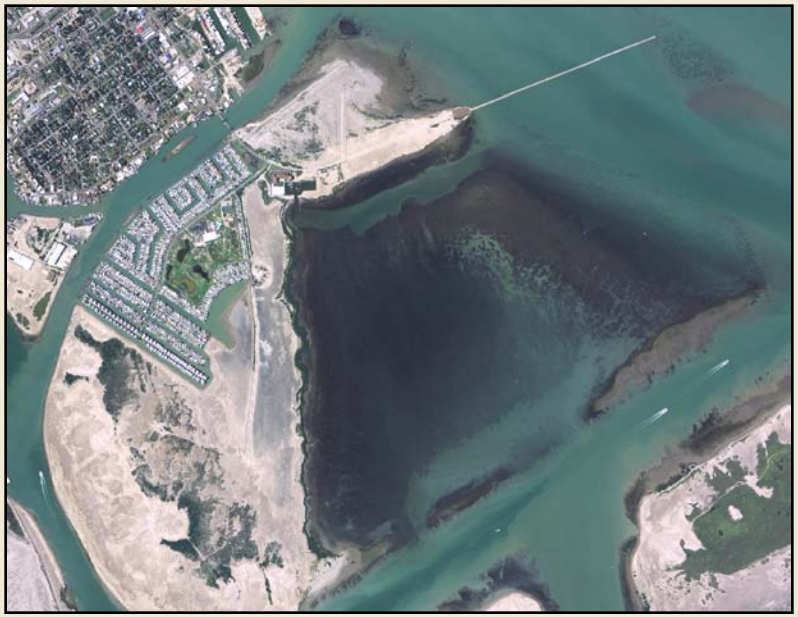
Project Area-Texas Coastal Bend

- 2 Bay systems for phase 2
  - Lower Laguna Madre
  - San Antonio Bay
- ~1200 miles^2
- Mapping inside barrier island systems



Source Imagery

- Lower Laguna Madre
  - 2004 NAIP imagery
  - 1m ADS40 digital airborne imagery, resampled to 2m for classification
  - Reprocessed true color and CIR



- San Antonio Bay
  - 1m UltraCam digital airborne imagery collected in November 2007
  - Resampled to 2m for classification

What are we mapping?

- Underwater and emergent habitats
  - Continuous SRV (Seagrass)
  - Patchy SRV
  - Oysters
  - Unconsolidated Sediments
  - Annelid Reef
  - Unknown Benthic Habitat
  - Mangroves
  - Emergent Marsh
  - Land
- Our classification scheme derived from the Florida System for Classification of Estuarine and Marine Environments (SCHEME)
- Minimum Mapping Unit 100 m^2

Classification Scheme Rules

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

- If greater than 10% of cover consists of Submerged Rooted Vascular Plants (SRV), then SRV (21).
  - If SRV cover is greater than or equal to 75% total coverage, then **Continuous SRV (211)**
  - Else **Patchy (Discontinuous) SRV (212)**

Else if SAV cover is greater than 10% and reef/hardbottom cover is greater than SAV cover, then **Reef/Hardbottom (3).**

Else if SAV cover is less than 10%, and unconsolidated sediments are greater than 90% total coverage, then **Unconsolidated Sediments (1).**

Else if SAV cover is less than 10% and greater than 10% of substrate is reef/hardbottom, then Reef/Hardbottom (3)

- If reef/hardbottom consists of greater than 50% sessile mollusks, then Mollusk Reef (32)
  - If mollusk reef consists of greater than 50% oysters, then **Bivalve Reef (321)**
- Else if reef/hardbottom consists of greater than 50% of annelid worm tubes, then **Annelid Reef (33)**

Else **Unknown Benthic Habitat (7)**

Project Methods

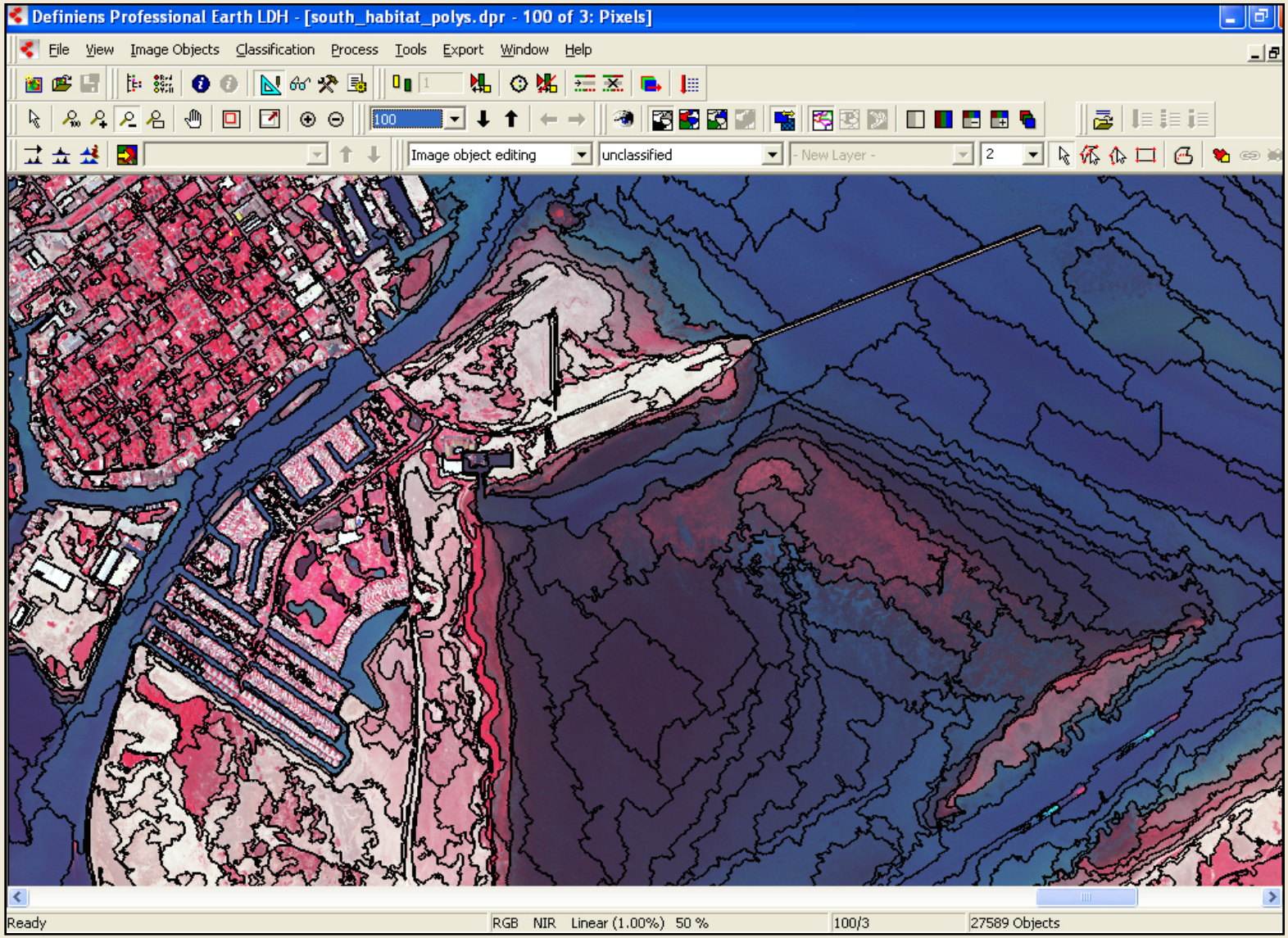
1. Collection of ancillary data
2. Image segmentations of imagery to create habitat polygons for classification – Definiens Professional
3. Calibration field trip to understand variation on the ground (water)
4. Collection of offices sites to supplement field data
5. Polygon labeling using Classification and Regression Tree (CART) analysis – initial map
6. Review of initial map by NOAA and Texas partners
7. Validation field trip to resolve confusion/errors in classes
8. Continue map revisions through editing and modeling – Draft Map
9. Review of draft map by NOAA and Texas partners
10. Final map edits
11. Final accuracy assessment

Classification And Regression Tree (CART) Analysis

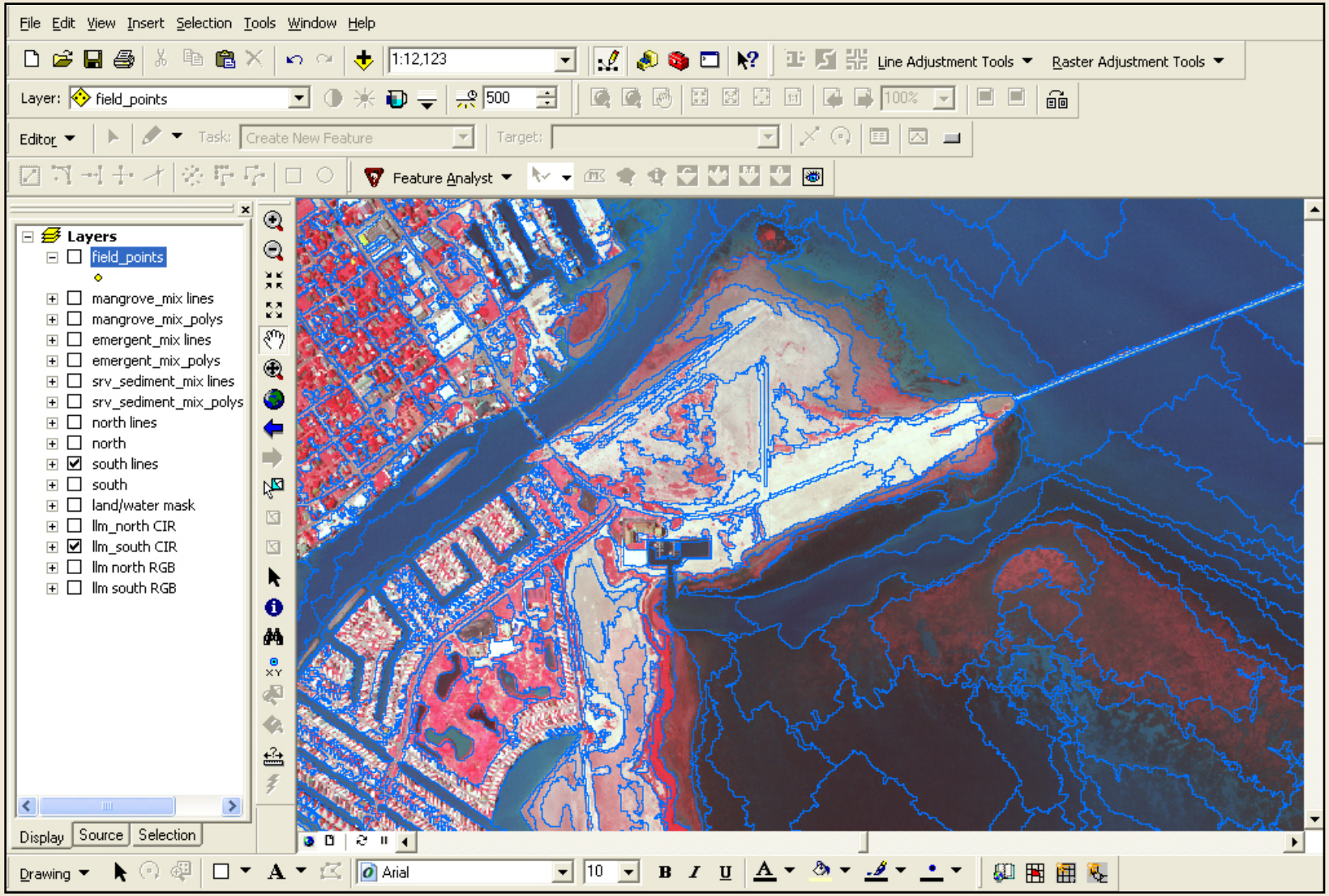
- A statistical analysis that predicts variables (class) from multiple independent variables
- “Mines” your independent variables and builds a hierarchical tree diagram (set of “if-then” statements) to predict your dependent variables
  - Classification rules
- CART is powerful:
  - Can accept both continuous (raster) and categorical (vector) data inputs
  - Results are easy to interpret
  - No assumptions about independent data distributions
  - Can find simple and complex relationships between variables that other techniques might not uncover

2m ADS40 CIR – Port Isabel, Texas (Lower Laguna Madre)

Polygons Created in Definiens Professional



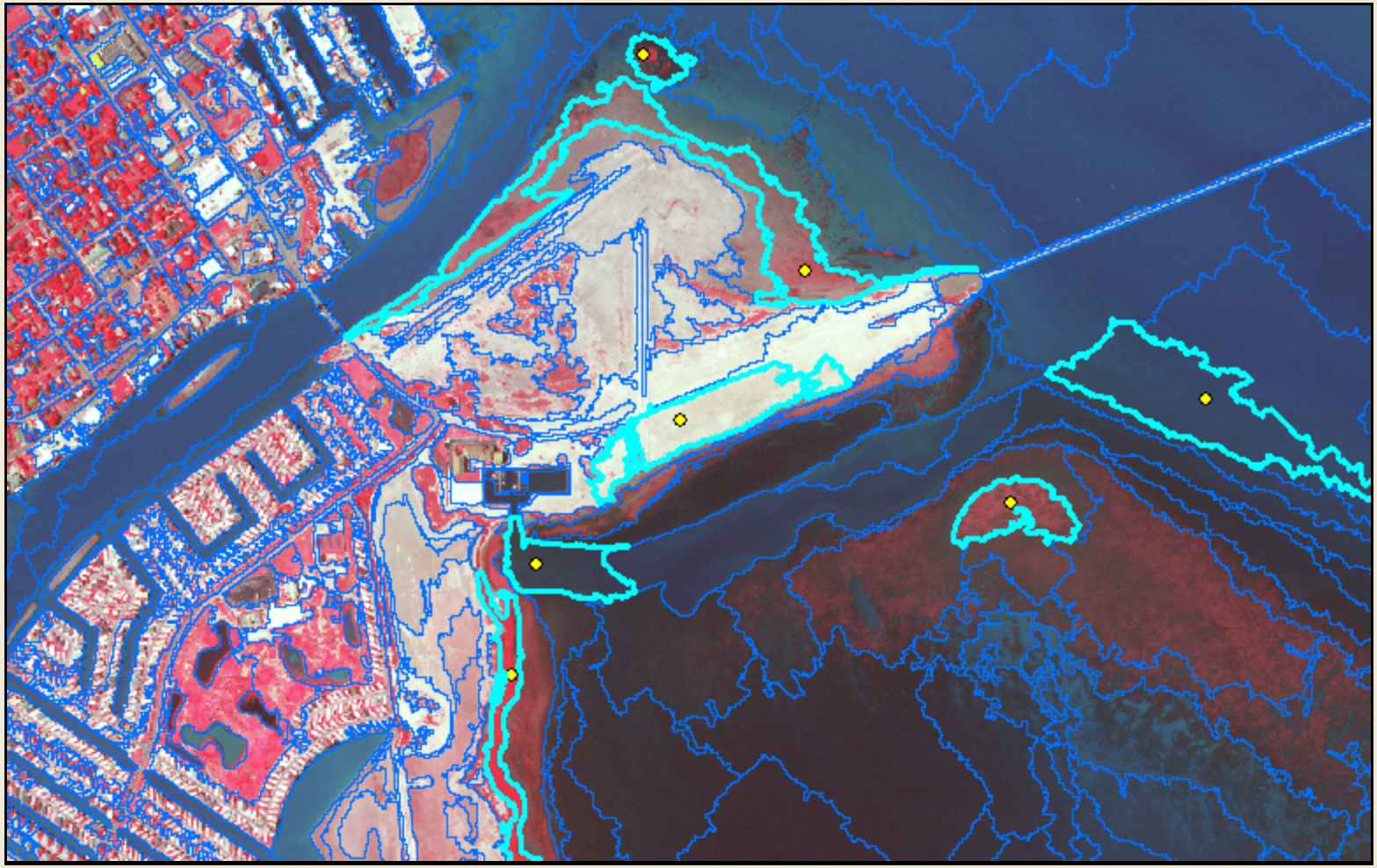
Polygons Exported to Shapefile



Polygon Attributes

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	OBJECTID	ECOG_ID	CLASS	BORDERII	ROUNDNE	BRIGHTNI	COMPAC	SHAPEIND	MEAN_NII	MEAN_RE	MEAN_GF	MEAN_BL	MEAN_G_	MEAN_G_	MEAN_NII	MEAN_NII	MEAN_ND	SD_NIR	SD_RED	SD_GREE
2	1	0		2.930	1.980	141.670	2.750	3.050	180.000	138.180	150.700	125.160	177.770	117.040	150.080	117.890	118.190	12.070	17.910	15.910
3	2	1		1.240	0.640	133.880	1.570	1.460	176.060	98.230	114.570	97.260	175.450	121.860	163.540	126.630	131.290	11.820	16.950	15.860
4	3	2		1.500	1.010	156.690	1.910	2.030	220.140	166.450	175.520	144.170	178.890	115.420	154.860	127.500	127.280	5.940	35.990	30.060
5	4	3		3.210	1.530	142.660	2.340	4.030	211.260	102.600	121.430	103.880	173.960	123.610	171.310	135.110	140.780	12.200	23.840	22.380
6	5	4		2.000	1.080	153.110	1.760	3.080	205.430	163.880	175.570	151.170	173.360	115.920	147.140	123.100	122.400	8.820	24.720	23.120
7	6	5		4.380	4.460	132.300	10.120	4.470	155.930	116.970	131.370	108.310	178.390	118.890	149.900	114.800	116.170	17.330	6.480	6.920
8	7	6		3.920	1.420	107.960	2.200	4.590	97.680	65.040	89.110	72.260	179.530	133.650	143.490	93.980	96.910	25.710	11.880	12.450
9	8	7		1.760	0.580	171.840	1.570	1.880	240.550	209.350	216.820	183.650	175.570	113.130	144.110	130.990	132.430	1.300	3.110	2.730
10	9	8		3.880	1.750	155.240	2.890	4.250	219.140	158.670	172.910	148.380	174.070	116.840	151.600	127.240	128.310	5.260	7.790	6.480
11	10	9		3.230	1.650	154.420	2.160	3.780	213.870	164.660	172.390	144.450	176.840	113.910	151.650	125.820	126.210	6.480	5.820	5.250
12	11	10		2.090	0.920	167.190	1.660	2.270	234.690	203.580	204.100	170.950	176.840	110.850	147.030	128.660	128.060	3.340	4.660	3.900
13	12	11		1.910	1.030	131.100	1.970	2.020	158.590	105.230	121.450	101.150	177.480	120.980	155.260	117.880	121.880	8.080	9.150	8.650
14	13	12		2.770	1.520	129.280	2.220	2.820	161.190	62.390	85.360	69.650	179.560	133.490	176.810	137.740	157.380	26.110	11.230	11.090
15	14	13		5.680	2.580	133.730	4.360	6.090	165.880	109.910	125.710	103.290	179.030	120.470	156.810	119.600	122.910	9.880	14.000	12.700
16	15	14		4.030	1.680	140.090	2.550	4.190	178.440	131.850	144.710	119.060	178.860	117.460	152.610	118.680	119.140	9.970	15.410	14.000
17	16	15		3.090	1.930	123.870	3.970	3.360	139.850	61.790	83.800	68.960	178.470	132.990	167.940	131.270	149.760	36.320	12.290	12.090
18	17	16		3.950	1.510	129.470	2.370	4.040	161.530	61.970	85.390	69.380	180.150	133.780	177.380	138.020	157.630	21.610	9.070	9.120
19	18	17		2.220	1.080	126.780	1.940	2.260	147.560	84.160	102.760	83.210	180.740	125.190	162.650	123.090	131.690	9.840	11.030	9.900
20	19	18		2.920	2.280	133.660	3.590	4.220	161.030	117.970	135.070	107.850	182.250	120.800	151.190	115.510	111.270	30.350	21.190	19.520
21	20	19		1.790	0.730	120.550	1.630	1.840	125.730	68.730	89.180	73.150	179.190	129.910	160.240	121.960	136.830	18.850	14.380	13.060
22	21	20		1.980	1.690	93.540	2.120	2.000	41.090	75.860	104.970	76.360	192.790	133.830	88.620	56.640	71.690	3.450	5.680	6.210
23	22	21		1.360	0.400	92.500	1.270	1.480	41.360	69.180	96.660	71.760	190.530	134.450	92.700	59.560	76.290	2.760	2.930	3.270
24	23	22		4.490	5.340	106.070	11.010	4.760	69.990	72.440	95.250	75.210	182.830	129.240	127.580	91.070	110.970	16.850	4.710	6.120
25	24	23		6.850	4.180	126.950	12.700	7.510	146.920	87.230	106.500	86.390	180.440	125.110	159.890	120.620	129.450	21.240	12.520	10.980
26	25	24		1.990	1.270	129.850	2.100	2.140	165.970	64.510	86.850	72.140	177.390	132.330	176.150	138.030	155.260	29.970	12.380	12.470
27	26	25		1.880	0.280	123.050	1.380	1.890	136.230	62.790	85.060	70.920	177.410	132.350	166.730	129.090	146.880	16.140	5.340	5.070
28	27	26		3.440	1.930	142.800	3.210	3.950	191.440	128.060	142.140	117.540	178.080	118.730	158.400	124.700	126.150	11.920	23.560	20.790
29	28	27		3.860	2.550	130.650	3.560	4.070	165.870	72.090	94.600	76.910	180.190	130.110	173.530	133.590	148.950	10.090	6.370	5.740
30	29	28		5.820	3.270	132.120	7.230	6.050	167.530	94.160	111.750	92.590	178.140	123.270	164.080	125.510	132.040	13.390	13.040	11.680
31	30	29		3.590	2.130	146.530	3.550	3.770	199.670	138.520	151.750	126.090	177.620	117.820	156.710	124.920	125.620	12.360	26.300	23.310
32	31	30		2.180	0.760	132.600	1.480	2.230	176.920	74.790	96.220	79.830	177.790	129.030	174.910	135.300	148.600	17.510	12.720	11.770
33	32	31		2.210	1.500	144.690	2.070	2.270	192.170	140.320	152.320	127.780	176.580	116.780	153.140	121.840	121.320	9.630	16.080	14.680
34	33	32		2.920	2.190	144.660	3.220	3.060	195.800	134.310	147.890	124.040	176.440	118.060	156.390	124.360	124.680	9.280	21.870	19.280
35	34	33		2.390	1.190	130.040	1.810	2.600	162.580	95.400	111.020	93.870	175.800	121.560	161.200	122.420	126.520	6.710	7.450	6.930
36	35	34		5.190	2.150	135.570	4.190	5.270	175.020	112.960	127.320	107.740	175.680	119.280	157.390	121.420	123.350	6.660	8.060	7.370
37	36	35		1.930	1.140	146.120	1.590	2.160	200.970	138.020	150.280	124.430	178.190	116.790	157.140	124.700	124.560	3.210	8.170	7.250
38	37	36		4.120	1.680	141.130	2.390	4.440	192.640	122.360	135.970	113.300	177.420	118.290	160.190	124.470	125.560	4.330	7.000	6.370
39	38	37		1.810	0.610	136.670	1.730	1.890	194.460	66.340	91.880	73.210	182.440	133.910	184.670	142.370	160.740	15.140	5.230	6.130
40	39	38		4.090	2.120	130.450	3.200	4.930	167.750	81.600	100.550	83.520	177.880	125.900	170.070	128.790	137.970	6.830	7.640	6.830
41	40	39		3.190	1.440	131.040	2.520	3.610	171.130	81.360	100.460	84.070	176.910	125.710	170.420	130.290	138.990	7.070	7.900	6.960
42	41	40		2.980	1.660	137.760	2.590	3.270	188.410	107.240	123.000	103.020	176.830	120.510	164.360	126.940	129.500	6.610	9.600	9.020
43	42	41		3.170	1.140	148.420	2.200	3.240	205.380	143.920	156.120	130.560	176.860	116.690	155.860	125.370	124.980	6.910	16.920	15.480

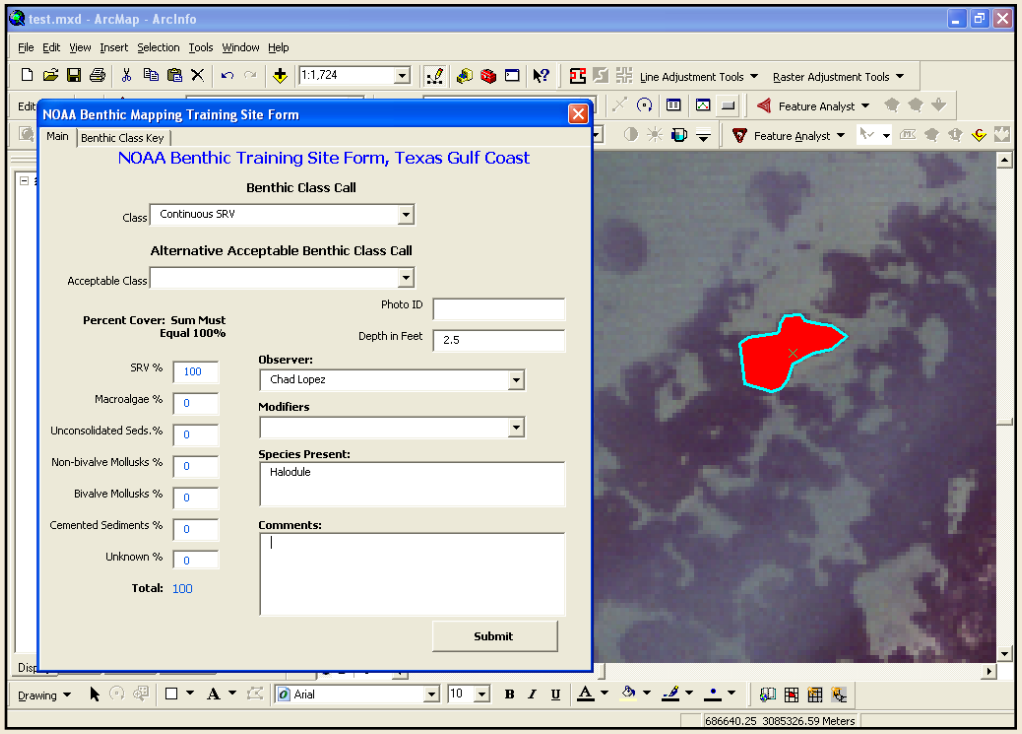
Selecting Field Sites to Visit



Collecting Field Data

Field Equipment

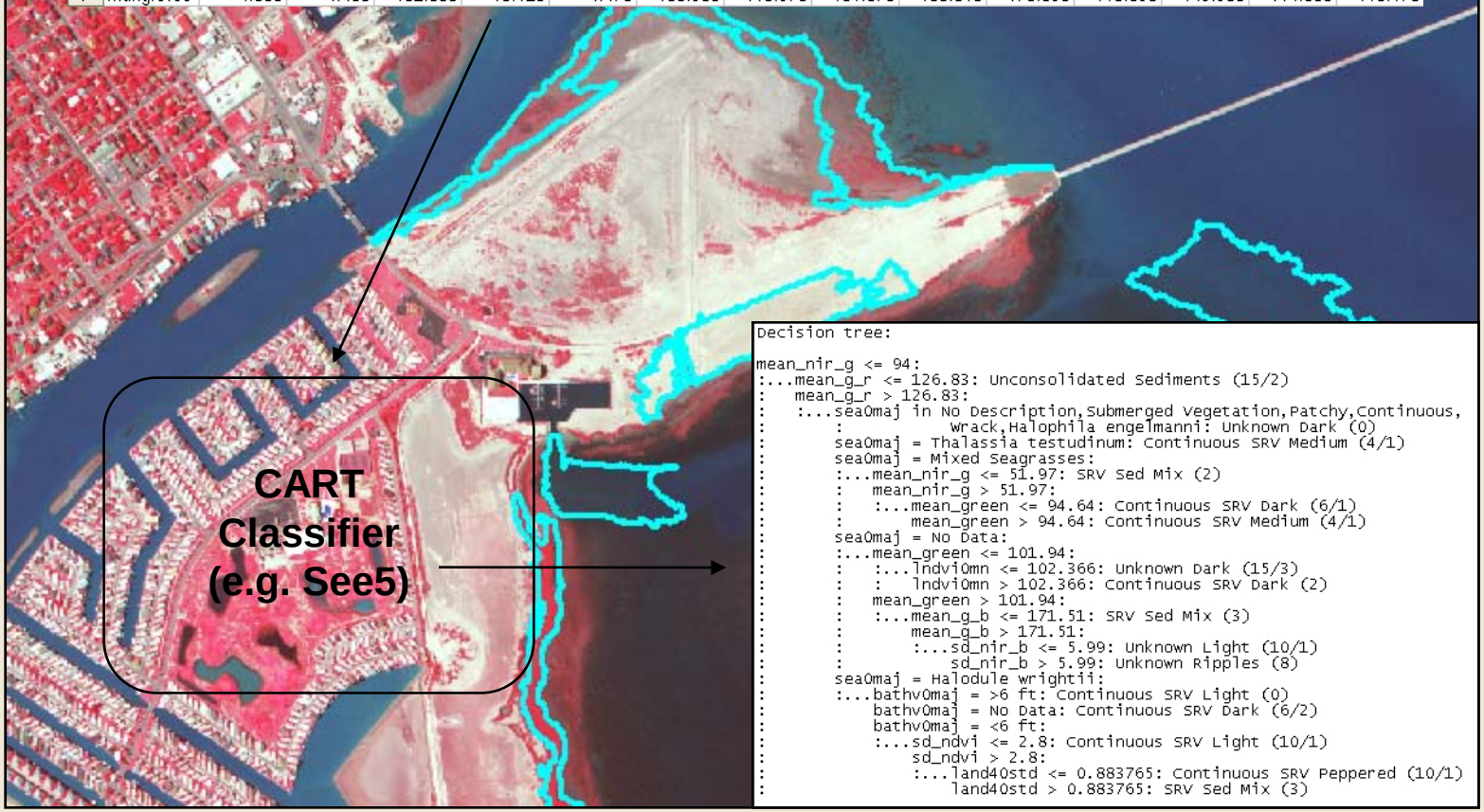
- Laptop with imagery, polygons, field points
- GPS with field points
- GPS connected to laptop for navigation
- Underwater camera and video



Digital field form for collecting data. Data are stored directly in a shapefile.

Sample Polygons Input into CART

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	CLASS	BORDERII	ROUNDNE	BRIGHTNE	COMPACT	SHAPEIND	MEAN_NIF	MEAN_RE	MEAN_GF	MEAN_BL	MEAN_G_	MEAN_G_	MEAN_NIF	MEAN_NIF	MEAN_ND
2	Seagrass	2.930	1.980	141.670	2.750	3.050	180.000	138.180	150.700	125.160	177.770	117.040	150.080	117.890	118.190
3	Sediments	1.240	0.640	133.880	1.570	1.460	176.060	98.230	114.570	97.260	175.450	121.860	163.540	126.630	131.290
4	Land	1.500	1.010	156.690	1.910	2.030	220.140	166.450	175.520	144.170	178.890	115.420	154.860	127.500	127.280
5	Seagrass	3.210	1.530	142.660	2.340	4.030	211.260	102.600	121.430	103.880	173.960	123.610	171.310	135.110	140.780
6	Sediments	2.000	1.080	153.110	1.760	3.080	205.430	163.880	175.570	151.170	173.360	115.920	147.140	123.100	122.400
7	Mangroves	4.380	4.460	132.300	10.120	4.470	155.930	116.970	131.370	108.310	178.390	118.890	149.900	114.800	116.170

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Decision tree:

mean_nir_g <= 94:
:...mean_g_r <= 126.83: Unconsolidated Sediments (15/2)
:   mean_g_r > 126.83:
:   :...sea0maj in No Description,Submerged Vegetation,Patchy,Continuous,
:       :           Wrack,Halophila engelmanni: Unknown Dark (0)
:       sea0maj = Thalassia testudinum: Continuous SRV Medium (4/1)
:       sea0maj = Mixed Seagrasses:
:       :...mean_nir_g <= 51.97: SRV Sed Mix (2)
:       :   mean_nir_g > 51.97:
:       :   :...mean_green <= 94.64: Continuous SRV Dark (6/1)
:       :       mean_green > 94.64: Continuous SRV Medium (4/1)
:       sea0maj = No Data:
:       :...mean_green <= 101.94:
:       :   :...lndvi0mn <= 102.366: Unknown Dark (15/3)
:       :   :   lndvi0mn > 102.366: Continuous SRV Dark (2)
:       :   mean_green > 101.94:
:       :   :...mean_g_b <= 171.51: SRV Sed Mix (3)
:       :       mean_g_b > 171.51:
:       :       :...sd_nir_b <= 5.99: Unknown Light (10/1)
:       :           sd_nir_b > 5.99: Unknown Ripples (8)
:       sea0maj = Halodule wrightii:
:       :...bathv0maj = >6 ft: Continuous SRV Light (0)
:           bathv0maj = No Data: Continuous SRV Dark (6/2)
:           bathv0maj = <6 ft:
:           :...sd_ndvi <= 2.8: Continuous SRV Light (10/1)
:               sd_ndvi > 2.8:
:               :...land40std <= 0.883765: Continuous SRV Peppered (10/1)
:                   land40std > 0.883765: SRV Sed Mix (3)
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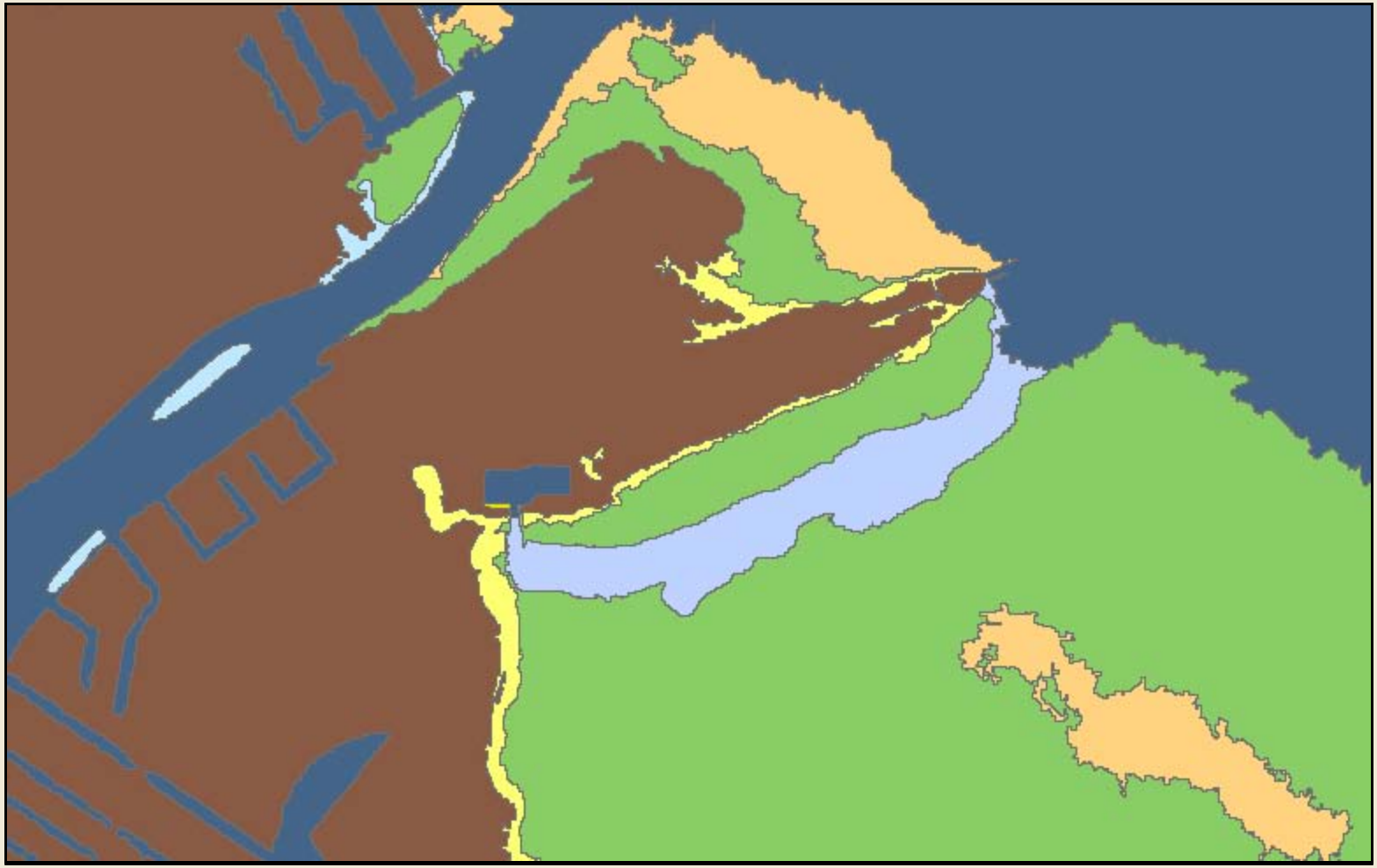
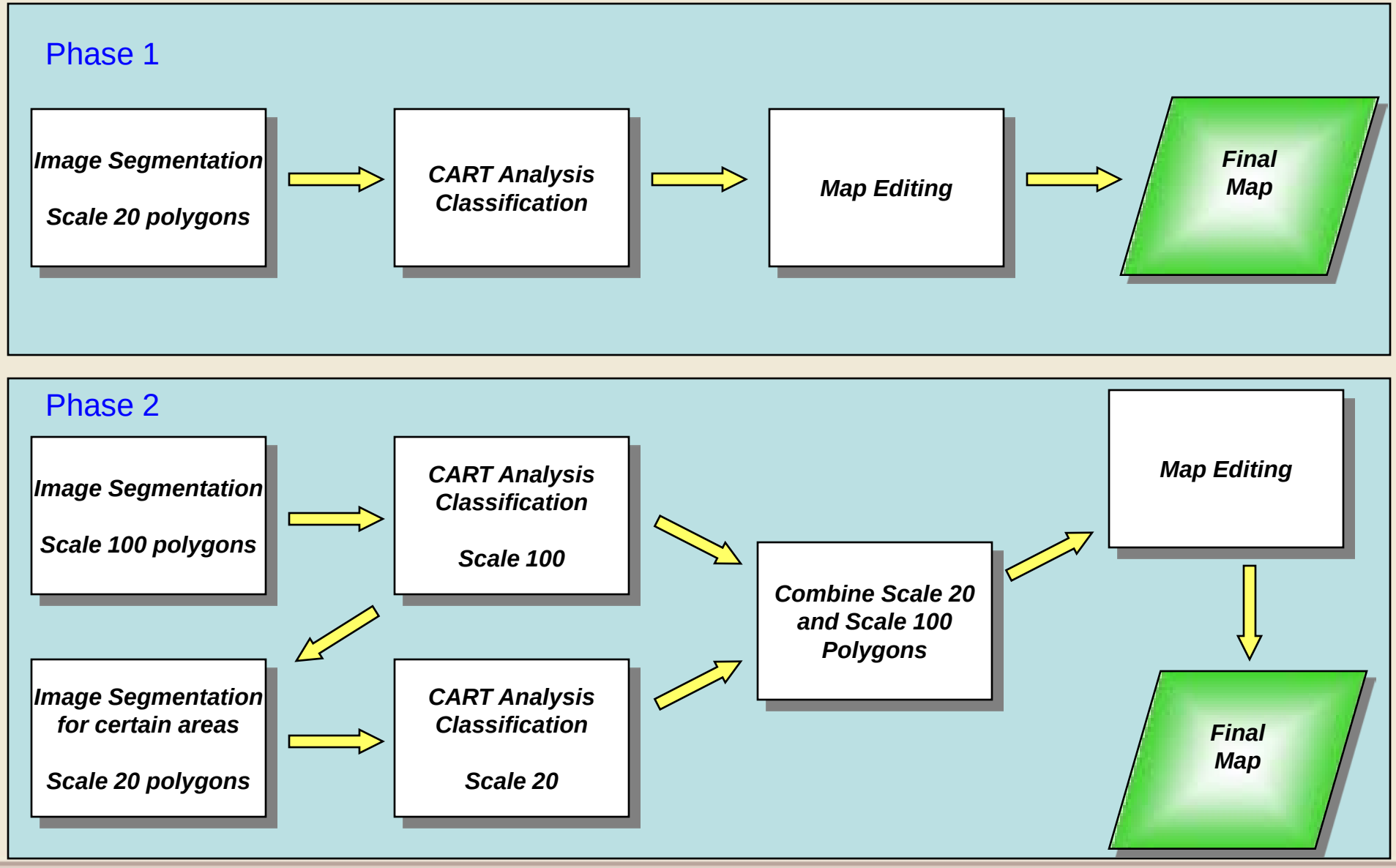
CART Polygon Labeling and Final Editing



Phase 1 vs. Phase 2 Methodologies



Phase 1 vs. Phase 2 Statistics

Phase 1

- Project area 1406 mi^2
- 2.6 million initial polygons

Phase 2

- Project area 1170 mi^2
- 250,000 initial polygons

During final editing phase (time from final CART analysis to final map delivery):

- Direct comparison – time spent editing during phase 2 was about 44% less than phase 1
- Adjusting for difference in project area size - time spent editing during phase 2 was about 33% less than phase 1
- The actual difference is probably larger but we did not have detailed enough figures to calculate

Error Matrix – Phase 1 CART Map

	Habitat Class	Reference Sites								
		SRV	Unconsolidated Sediments	Bivalve Reef	Unknown Habitat	Emergent Marsh	Mangroves	Land	Total	User's Accuracy
Map	SRV	72	46	21	11	4		3	157	46%
	Unconsolidated Sediments	9	27	1	2			1	40	68%
	Bivalve Reef	9	11	80	4			1	105	76%
	Unknown Habitat	5	7	3	83	1			99	84%
	Emergent Marsh	4	6	4		89	6	6	115	77%
	Mangroves						88		88	100%
	Land		3	1		6	6	89	105	85%
	Total	99	100	110	100	100	100	100	709	
	Producer's Accuracy	73%	27%	73%	83%	89%	88%	89%		74%

Error Matrix – Phase 2 CART Map

	Habitat Class	Reference Sites								
		SRV	Unconsolidated Sediments	Bivalve Reef	Unknown Habitat	Emergent Marsh	Mangroves	Land	Total	User's Accuracy
Map	SRV	73	14	2	4	1	3		97	75%
	Unconsolidated Sediments	22	37	3		9	1	2	74	50%
	Bivalve Reef			17					17	100%
	Unknown Habitat		5	8	55				68	81%
	Emergent Marsh					39	2	3	44	89%
	Mangroves					13	58		71	82%
	Land		4			3	1	55	63	87%
	Total	95	60	30	59	65	65	60	434	
	Producer's Accuracy	77%	62%	57%	93%	60%	89%	92%		77%

Error Matrix – Phase 1 Final Map

	Habitat Class	Reference Sites								
		SRV	Unconsolidated Sediments	Bivalve Reef	Unknown Habitat	Emergent Marsh	Mangroves	Land	Total	User's Accuracy
Map	SRV	97	58	5		8			168	58%
	Unconsolidated Sediments	1	110	3		5	1	1	121	91%
	Bivalve Reef			99					99	100%
	Unknown Habitat	1	6	3	100			1	111	90%
	Emergent Marsh					60			60	100%
	Mangroves						97		97	100%
	Land		1			17	2	70	90	78%
	Total	99	175	110	100	90	100	72	746	
	Producer's Accuracy	98%	63%	90%	100%	67%	97%	97%		85%

Error Matrix – Phase 2 Final Map

	Habitat Class	Reference Sites								
		SRV	Unconsolidated Sediments	Bivalve Reef	Unknown Habitat	Emergent Marsh	Mangroves	Land	Total	User's Accuracy
Map	SRV	85	6			1	1		93	91%
	Unconsolidated Sediments	10	48	1	1	4		2	66	73%
	Bivalve Reef			43					43	100%
	Unknown Habitat		6	1	58				65	89%
	Emergent Marsh					51	2	3	56	91%
	Mangroves					6	61		67	91%
	Land					3	1	55	59	93%
	Total	95	60	45	59	65	65	60	449	
	Producer's Accuracy	89%	80%	96%	98%	78%	94%	92%		89%

Conclusions

- The multiscale polygon approach in phase 2 resulted in less editing time compared to phase 1 and less time overall
- No significant difference between Lower Laguna Madre (ADS40) and San Antonio Bay (UltraCam) final maps
- Kappa analysis shows that phase 2 final map is significantly better than phase 1 final map (Z = -2.249)
- Improved upon phase 1 methodology

Apply Benthic Mapping Methods to Another Ecosystem

- Using these methods to map benthic habitats in St. Lucia
- Collected 75cm ADS40 imagery in December 2007/January 2008
- Mapping seagrasses, corals, and mangroves for a portion of the island

The End