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Tampa Bay Oyster Bar Mapping and Assessment

Final Report to Tampa Bay Estuary Program

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Fish & Wildlife Research Institute
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Project Summary

The objectives of this mapping exercise were to establish a baseline map layer for the current extent of oysters within Tampa Bay, to assess the accuracy of the mapping effort, and to develop an historic map layer derived from scanned USGS post-1927 T-sheets. These efforts will provide the base data for future mapping projects and enable trend analyses to be performed that will aid scientists in monitoring changes to oyster resources inTampa Bay.

In addition to identifying oysters within the Bay, there was a desire to ascertain if the mapping of this resource is something that can be automated. Currently, maps are most often produced using ground surveys and manual interpretation of aerial photographs. These techniques are time-consuming and labor intensive. An integrated automated mapping method that incorporates high resolution sources (spectral and spatial) at a lower cost would be a useful tool for resource managers in Tampa Bay as well as may other areas. If a remote sensing method can be proven to secure reliable results, it will enable mapping of oysters on a large geographic scale. This would be efficient as well as economical. To this end, two separate semi-automated feature extraction approaches were employed as well as traditional photointerpretation methods.

Staff at the Fish& Wildlife Research Institute (FWRI) performed mapping, field verification and quality assurance on all products. For this effort, hyperspectral imagery collected by the Galileo-Group, Inc.(Galileo) and 2004 digital orthophoto quarter quadrangles (DOQQs) were used. Extensive field reconnaissance was performed to provide training sets as well as to identify errors of commission and omission.

Project Details

Historic Charts

FWRI staff processed two types of digital charts. The first consisted of the scanned 1927 USGS T-Sheets, acquired from the University of Florida's Publication of Archival, Library & Museum Materials. Fourteen T-Sheets were geo-referenced and combined to create one mosaic. The second type of chart is the 1:40,000 scale NOAA nautical charts, acquired from the US Geological Survey. For each year, two nautical charts were combined to make one mosaic. The nautical charts included the following years: 1928, 1930, 1935, 1943, 1959, 1969, 1978, and 1988.

These scanned and geo-referenced images as well as the associated metadata are available via the image server site that FWRI created for the Tampa Bay Estuary Program (TBEP). This site offers the ability to blend and swipe layered images in order to view changes through time. The url for that site is **http://ocean.floridamarine.org/tbep/**

Originally, it was planned to use the historic U.S. Coast and Geodetic Survey T-Sheets and nautical charts to plot a vector layer depicting the location of historic oyster beds and reefs. Unfortunately, a legend corresponding to the charts could not be located. Without a clear legend describing the symbology depicted on the charts, creating a vector layer would have been guesswork. It was determined that the best solution possible was to offer geo-referenced mosaics viewable through the TBEP site. This solution permits overlay by vector datasets and viewing of multiple years simultaneously. Changes over time can be easily evaluated this way.

Mapping Effort

Hyperspectral Approach

Hyperspectral imagery, comprising 128 spectral bands, was collected at low tide for the nearshore of Tampa Bay, and of Boca Ciega Bay from its southern terminus north to the "Narrows" at 1.5 and 2 meter ground resolution.

The Flight Plan is shown as Figure 1 below, while the Flight Log is attached as Attachment 1. The flight was planned to correspond with the low tide cycle so that the intertidal areas of the Bay would be exposed. The Galileo Group flew the area on May 21, 2005 and performed the hyperspectal analyses. In addition, 2004 high resolution ADS40 digital orthophoto quarter quadrangles (DOQQs) were used as an ancillary source of imagery.

Figure 1: Flight Plan

Field reconnaissance was conducted by helicopter on February 9th and July 18th during periods of low tide with clear water conditions. Digital imagery was collected to aid in the identification effort. Ground surveys were accomplished on foot as well as through the use of kayaks and FWRI boats. GPS units were used to acquire location information on points representing homogenous oyster beds as well as locations that were heterogeneous, like oyster/shell mixtures. These field collection points were used to “train” the analyses, to separate clear from confused signatures, and to obtain data points to be used in the accuracy assessment. Figures 2 and 3 provide a visual example of the differences realized by viewing the imagery obliquely and from aerial photography. Field Reconnaissance Notes are attached as Attachment 4.

Figure 2: Tarpon Key Oblique Image

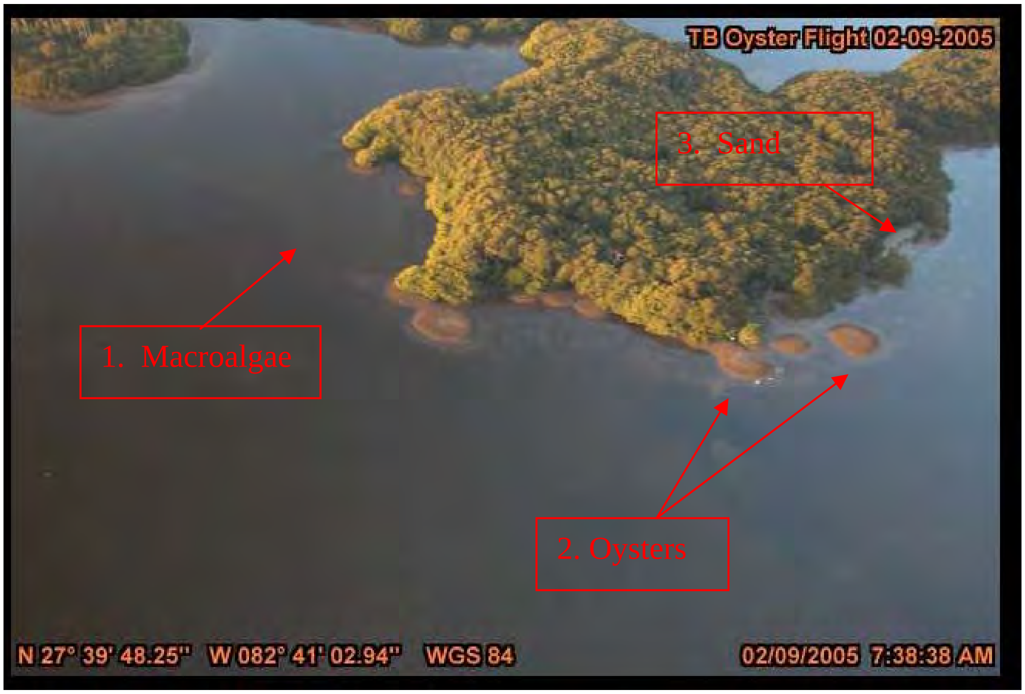
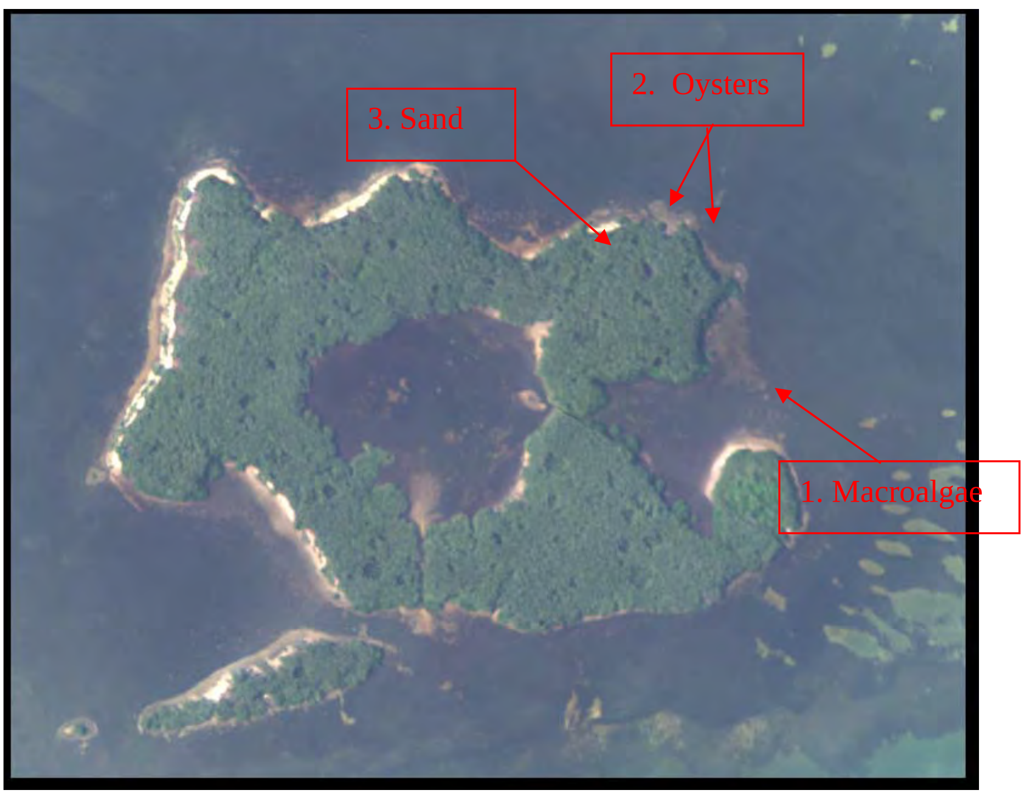


Figure 3: Tarpon Key Aerial Photo



Galileo applied proprietary algorithms to extract the oyster signatures from the hyperspectral imagery. Three iterations of the image processing were performed by Galileo. Through this iterative process, Galileo separated out the digital signatures that corresponded to the oysters anticipated in the field. To generate maps, Galileo used geo-referenced false color highlights against natural color representation from the hyperspectral data. The predicted automated airborne measured ground accuracy for this effort was five meters.

During one field trip, disagreement was noted in two components of the image processing: 1) there was a minor offset in the geographic location information used in the hyperspectral effort; 2) in several instances, sand flats were identified as oyster reefs by the hyperspectral algorithm. The offset was corrected and Galileo attempted to correct the misidentification of sand flats.

Galileo provided a finished map of oyster bed presence and corresponding shape files of mapping results as well as the raw and finished radiance corrected post-processed hyperspectral data. To test the Galileo product, additional field work was conducted. An error matrix was developed using 1229 points that were identified through the field verification phases as being oyster beds or fringing reefs.

Feature Analyst Semi-Automated Approach

Feature Analyst, a software developed by Visual Learning Systems, was used as a secondary method to test the feasibility of automating oyster mapping efforts. This software operates by using a suite of machine learning algorithms that "learn" how to classify the object-specific geographic features. Some of these learning algorithms, like Nearest Neighbor and Neural Networks, are used to extract features that have been specified by the user.

A Nearest Neighbor algorithm was selected and customized with a *Bulls-eye 3* input representation pattern after masking the land and water deeper than 6 feet. FWRI staff used field data points to "train" the software. A minimum of 4 iterations were performed on each output from Feature Analyst at each stage of the process for a total of approximately 30 iterations to test this approach. Feature Analyst used the results of each progressive iteration along with the initial settings for the first training set of a new iteration to "learn" about the feature being extracted from the imagery and to further refine the extraction parameters.

Traditional Photointerpretation Approach

For this effort, Galileo's low tide imagery was used to perform the photointerpretation. The 2004 DOQQs were used as ancillary data and to fill in areas that were obscured in the Galileo imagery. Galileo's imagery provided a much clearer picture at low tide when compared with the DOQQs. 90% of the full field collection data set was used to refine both the signatures and locational characteristics of the oyster habitat around the Bay.

Review

Early on it was decided that only free-standing or fringing reefs would be mapped. No oysters on rubble and seawall were targeted. Attempts were made to map oysters growing with mangroves. These were particularly problematic since the vertical relief of the tree canopy and consequent shadow obscured the oysters.

Vertical relief such as that found with the free-standing pristine reefs in South Carolina is not typical of oyster reefs in Tampa Bay. Additionally, oyster beds in Tampa Bay are often covered with macroalgae and/or mud and sand. This combination caused great confusion in the digital signatures.

After several iterations with the Feature Analyst software it was determined that we had reached a point of diminishing returns. Feature Analyst had a difficult time separating the different pixel values for oyster reefs. Fringing reefs seemed to be the most difficult for Feature Analyst to extract due to the shadows cast by the mangroves. Virtually all shadows were classified as oysters when using the DOQQs. The software also classified too many areas as oysters that were actually mud, sand, or algae. Several different ground truth data sets were used to try to "train" the software to distinguish oyster reefs from sand, mud, algae and mixtures. This problem was experienced with both sources of imagery and all three feature extraction approaches. The low tide imagery supplied by Galileo fared much better overall with fewer mis-classified oyster reefs that were much smaller in area.

There is too little consistency in the digital signature of oysters in Tampa Bay for this automated approach to produce high accuracy. The decision was made to finish the feature extraction by traditional photointerpretation means. The following section describes the methods used to ascertain accuracy and also summarizes the results of the overall mapping effort

Assessment

At each site, we used an xGPS (Xplore Technologies) unit mounted on a Garmin ArcPad digital tablet to provide latitude/longitude location information for each sample point. Positional accuracy of this unit is stated to be 5 m or better. We first defined the perimeter of each selected reef by walking the perimeter and sampling at approximately 5 m intervals. We then randomly sampled a variable number of points within the reef. We also sampled a variable number of points in the surrounding area to test the signature emanating from structures such as seagrass, sand, and rock. Finally, we visited several sites that had been identified from the Galileo algorithm as being oyster reef, but that we knew from previous experience were not reefs, in an effort to determine what habitat features were being mischaracterized by Galileo. At each point within a site, we determined the actual habitat structure at that point. Stochastic tests of the accuracy and precision of our GPS unit indicated that we were able to 1) return during a single sampling event to a selected point within an error of approximately 1 m and 2) return on a subsequent date to that same location with an error of approximately 5m. Thus, some of the inconsistency between the Galileo mapping results and our field tests can be attributed to measurement error.

An error matrix (Table 1) was developed from a comparison of Galileo oyster reef locations versus actual reef locations determined from on-site sampling. This 2x2 matrix included a box containing the count of all points where Galileo predicted that oysters would be located and where we actually found oysters (yes-yes), a box where Galileo predicted that oysters would be located but where we did not find oysters (yes-no), and a box where Galileo did not find oysters but we determined oysters actually did exist (no-yes). The fourth box, describing locations where Galileo predicted that no oysters were located and where we did not find oysters, is not included because this would strongly bias the outcome towards success (an almost infinite number of no-no points could be located within Tampa Bay, thereby greatly increasing the percent agreement between the two methods). The success of the hyperspectral approach for mapping oyster reefs in Tampa Bay was determined from the percent of total points that were predicted to be oyster reef and actually were oyster reef. Since location error is inherent in both the Galileo and GPS approaches, points within 5 m of one another that were consistent in their substrate composition were considered to be in agreement.

Table 1

Hyperspectral Error Matrix

Galileo		FWRI Y	FWRI N
	Y	460 / 1424 32.3%	195 / 1424 13.7%
	N	769 / 1424 54.0%	Not Assessed

Note: All points buffered by 5 meters.
In situ information was collected for overall assessment of oysters in Tampa Bay

Hyperspectral Approach

To assess the accuracy of the final hyperspectral product, we selected fourteen sites (Table 2) dispersed throughout the general area of Tampa Bay (including Boca Ciega Bay) to identify habitat features of oyster reefs and surrounding areas. Data acquired from these sites were used for 3 purposes: to ground-truth the oyster extraction algorithm developed from the Galileo overflight and data processing efforts; to acquire data from habitats surrounding each reef; and to identify sites that were designated by the Galileo flight team as oyster reefs but that we knew *a priori* were not oyster reefs. The location of each ground-truth sample site is depicted in Figure 4. The complete summary table is included on the CD. An example of the Filed Data Collection sheets and excerpt of the summary table are provided in Figures 5 and 6 respectively.

Table 2: Sampling Locations

SITE TABLE

Site	Site Key	Points	Coordinate Center Points		Date	Approx. Field Time		Tide		
			Longitude (DMS)	Latitude (DMS)		Start	End			
Madeline Key	MAD	12	-82 42 45	27 38 49	09/01/05	10:05	11:30	6:43 L 1.4ft	13:08 H 2.6ft	
Pinellas Point Reef	PPR	20	-82 39 34	27 42 03	09/01/05	11:40	12:15	6:43 L 1.4ft	13:08 H 2.6ft	
Blackthorn Memorial Park	BTM	51	-82 40 49	27 39 07	09/07/05	8:20	10:15	2:10 H 2.1ft	8:56 L 0.5ft	15:16 H 1.8ft
Pinellas Point Reef	PPR	185	-82 39 34	27 42 03	10/05/05	8:45	11:40	2:47 H 2.4ft	9:59 L 0.2ft	16:36 H 2.0ft
Cockroach Bay	CRB	231	-82 30 12	27 42 29	10/06/05	8:50	14:45	2:09 H 2.5ft	9:55 L 0.1ft	16:34 H 1.7ft
Tarpon Key	TAK	144	-82 41 28	27 39 55	10/27/05	12:06	15:15	8:32 H 1.8ft	15:50 L 0.4ft	
Indian Key	IND	90	-82 41 27	27 42 08	10/27/05	15:25	17:15	8:32 H 1.8ft	15:50 L 0.4ft	22:30 H 1.7ft
The Narrows	NAR	95	-82 50 29	27 51 20	10/28/05	13:00	14:47	9:35 H 2.0ft	16:20 L 0.6ft	
Terra Ceia	TEC	164	-82 35 57	27 35 13	11/01/05	8:45	12:20	6:42 L 0.0ft	13:14 H 1.8ft	
Cross Bayou	CBA	180	-82 45 48	27 49 23	11/02/05	8:15	12:30	6:05 L - 0.2ft	12:52 H 1.7ft	
Upper Tampa Bay Park	UTB	176	-82 37 32	28 00 11	11/03/05	9:55	14:00	1:56 H 3.3ft	10:23 L - 0.4ft	17:10 H 2.1ft
Boca Ciega Bay	BCB	25	-82 47 07	27 48 27	01/31/06	12:00	14:30	7:46 L - 0.7ft	14:03 H 1.2ft	
Upper Tampa Bay Park	UTB	154	-82 37 32	28 00 11	02/01/06	12:00	16:30	11:56 L - 0.6ft	18:06 H 1.6ft	
North Gandy Bridge	NGB	125	-82 36 50	27 52 44	02/07/06	10:30	13:30	5:25 L - 0.6ft	21:03 H 2.2ft	

Figure 4: Hyperspectral Accuracy Sampling Sites

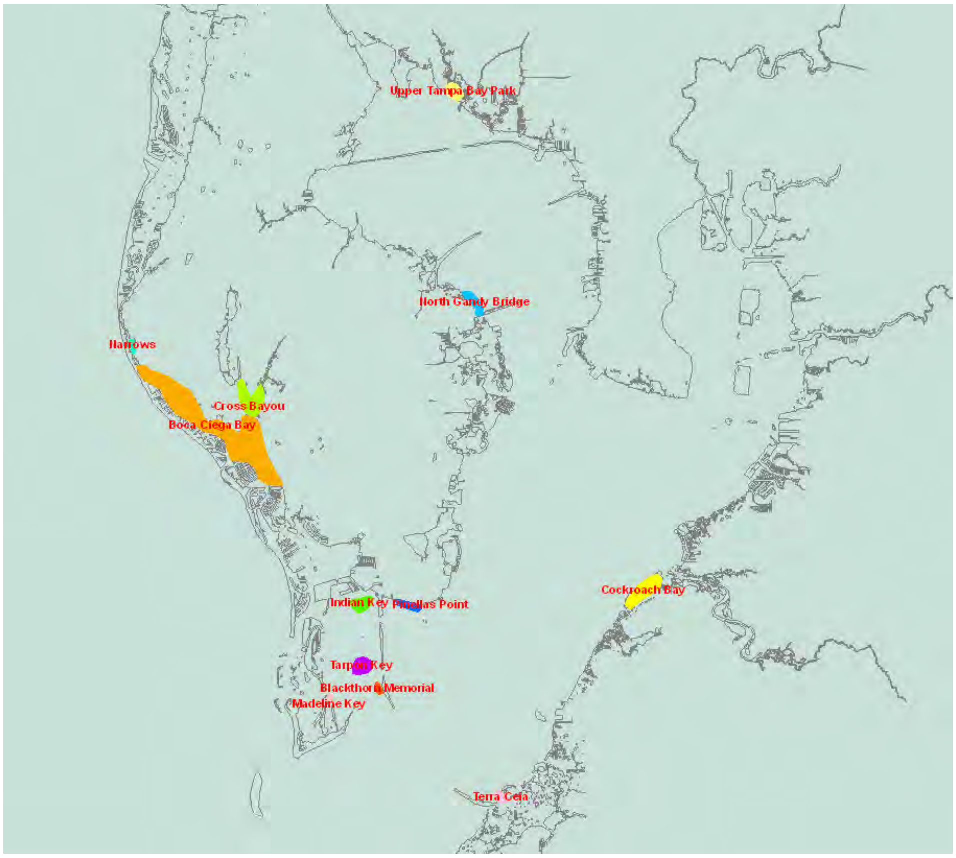


Figure 5: Field Data Collection Sheet

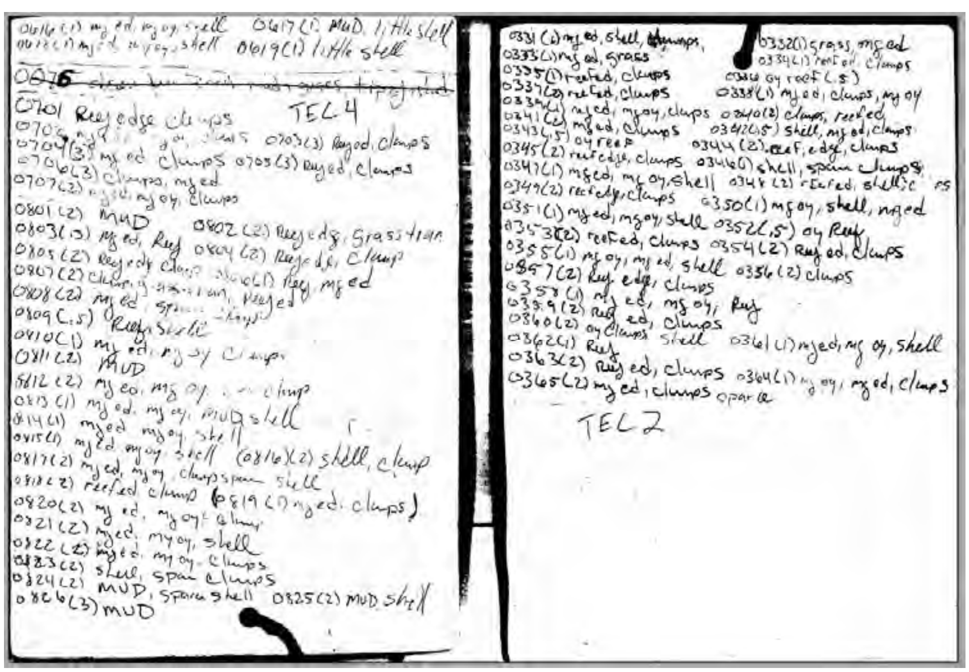


Figure 6: Field Summary Sheet
fieldwork 11-03-05mergek.xls (Excerpt. Entire Document included on CD)

ID	SITE	STATION	REPLICANT	LIVE	DATE	TIME	APROXDEPTH	HABITAT	COMMENTS	DEADSHELL	DRIFTALGAE	OTHERFAUNA	SOURCETHM	TRANSITION
0	MAD	01	01	yes	9/1/05	10:05am	3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	01	02	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	02	01	yes	9/1/05		3.5ft	sparse oyster clumps					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	MAD	02	02	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	02	03	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	02	04	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	02	05	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	MAD	02	06	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	MAD	00	01		9/1/05		3.5ft	mud/sand					fieldwork 11-2-05merge.dbf	mangrove to mud
0	MAD	01	03	yes	9/1/05		3.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	
0	MAD	00	02		9/1/05		3.5ft	mud/sand					fieldwork 11-2-05merge.dbf	
0	MAD	00	03		9/1/05		3-4ft	seagrass	observed from boat				fieldwork 11-2-05merge.dbf	
0	PPR	01	01	yes	9/1/05	11:40a	3ft	sparse oyster clumps					fieldwork 11-2-05merge.dbf	oyster to seagrass
0	PPR	01	02	yes	9/1/05		2.5ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	01	03	yes	9/1/05		3ft	sparse oyster clumps					fieldwork 11-2-05merge.dbf	oyster to seagrass
0	PPR	01	04	yes	9/1/05		2.5ft	oyster clumps/reef					fieldwork 11-2-05merge.dbf	oyster to seagrass
0	PPR	00	01		9/1/05		2ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	00	02		9/1/05		2ft	mud/sand					fieldwork 11-2-05merge.dbf	
0	PPR	01	05	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mud
0	PPR	01	06	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	01	07	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	00	03		9/1/05		3ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	02	01		9/1/05		2.5ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	02	02	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	02	03	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	00	04		9/1/05		2ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	00	05		9/1/05		2ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	00	06		9/1/05		2ft	seagrass					fieldwork 11-2-05merge.dbf	
0	PPR	02	04	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mud
0	PPR	02	05	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	
0	PPR	02	06	yes	9/1/05		2ft	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mud
0	PPR	00	07		9/1/05		2ft	seagrass					fieldwork 11-2-05merge.dbf	
0	BTM	01	01	yes	9/7/05	8:20am	>1ft	oyster reef	length 202ft btm0				fieldwork 11-2-05merge.dbf	oyster to mud
0	BTM	01	02	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	
0	BTM	01	03	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	
0	BTM	01	04	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	BTM	00	01		9/7/05		>1ft	mud/sand					fieldwork 11-2-05merge.dbf	
0	BTM	01	05	yes	9/7/05		exposed	oyster clumps					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	BTM	01	06	yes	9/7/05		exposed	oyster clumps					fieldwork 11-2-05merge.dbf	oyster to mangrove
0	BTM	01	07	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	
0	BTM	01	08	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	
0	BTM	01	09	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	
0	BTM	01	10	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mud
0	BTM	01	11	yes	9/7/05		exposed	oyster reef	width 83ft btm01-				fieldwork 11-2-05merge.dbf	oyster to mud
0	BTM	01	12	yes	9/7/05		exposed	oyster reef					fieldwork 11-2-05merge.dbf	oyster to mud
0	BTM	00	02		9/7/05		exposed	mud/sand					fieldwork 11-2-05merge.dbf	
0	BTM	00	03		9/7/05		exposed	mud/sand					fieldwork 11-2-05merge.dbf	
0	BTM	00	04		9/7/05		>1ft	seagrass					fieldwork 11-2-05merge.dbf	

Feature Analyst Approach

Accuracy of the final dataset was conducted by buffering 1229 known oyster locations by 5 meters (the predicted horizontal accuracy) and intersecting the GIS dataset. Of the 1568 total polygons created by Feature Analyst, 119 of them fell within 5 meters of the known oyster points producing about a 10% correct ratio for this semi-automated approach. At this point, Feature Analyst was abandoned in favor of the traditional photo interpretation approach. The final output from Feature Analyst was used as a starting point for this effort; polygons were removed that were incorrect and polygons added that Feature Analyst missed.

Traditional Approach

Of the 1229 verified oyster location points , 10% (123) were set aside to use as a control set in the quality assessment of the final product. The remainder of the known points was used as a guide to ensure that the proper photographic signature was identified and fell within the parameters of habitats observed in the field. Overall, 1720 polygons representing oysters in Tampa Bay were identified through this traditional method. Of the 123 points in the control set, 58 of these were identified as free-standing reefs, while 65 were identified as fringing. For the free-standing reefs, 84.8% accuracy was attained. As expected, for the fringing reefs, a lower accuracy was realized and only 72.3% of fringing reefs were identified. Overall accuracy for this method is 78%. The points that were mis-classified or missed have been rectified in the final product and are not part of the overall accuracy percentage.

Conclusions

Due to the generally low relief of the oysters found in Tampa Bay and the prevalence of mangrove islands with their canopy cover and abundant shadow, we experienced less than favorable results using semi-automated mapping techniques. While it is believed that semi-automated feature extraction is of great value in the mapping of natural resources, in this particular case, the resource and geographic locations did not lend themselves to effective use of these methodologies.

Using traditional methods, we have achieved an 85% accuracy for the free-standing reefs and 78% accuracy overall. The error matrix created for the hyperspectral effort indicates errors that are primarily of omission. We believe this is caused by the confusion of the spectral signature with sand, mud and algae due to the low relief observed with these habitats in the Bay. Additionally, as shown by the traditional method, errors of omission may be largely in the area of the fringing reefs.

Extensive field reconnaissance was crucial to this effort in Tampa Bay. Due to the problematic nature of the oysters within the mangrove islands and the prevalence of that form, estimated to be ~30% of total of all oysters observed, we believe that mapping these resources in the oblique may hold some promise. Mapping on the oblique may negate the feature extraction problems experienced due to canopy cover and shadow.

Deliverables

- ARC Shapefile representing the oyster coverage. The data are provided in Albers Equal Area Projection, NAD83, Meters.
- Digital geo-referenced images representing the historic oyster coverage
- Field Summary Sheet: fieldwork 11-03-05mergek.xls
- FWRI has posted these data on the TBEP internet map server http://ocean.floridamarine.org/tbep/
- Final Report
- Due to size constraints, FWRI will store a drive containing the following
    - Hyperspectral imagery of Tampa Bay in Geotiff format
    - Radiance Data in RAW format

Note: Since hyperspectral imagery was collected in 128 bands, a number of analyses can be performed on the imagery by determining appropriate bands for the targeted study. For example, this same imagery can be used to map presence/absence of seagrass. It is possible that some species identification may be determined.
Examples of band combinations are included for review and labeled Attachment 2.
True_color.jpg utilizes these values: Red: 641.37nm Green: 551.94nm Blue: 460.95nm
CIR.jpg utilizes these values: R: 861.49nm G: 650.82nm B: 551.94nm

Hyperspectral.jpg is a false color image depicting the probability of oyster bed mapping using rainbow color map. The rainbow color map changes from black->blue->green->yellow->red when the probability increases from 0 to 1.

Attachment 1: Galileo Flight Log

1.5 meter, 128 bands		**2.0 meter, 128 bands**
17 mm		**17 mm**
E:\Oyster\Vectors\T1.evf		E:\Oyster\Vectors\T1.evf
Total flight lines: 22		Total flight lines: 17
Total imaging distance: 39mile / 62km		Total imaging distance: 30mile / 49km
Average flight line length: 1.8mile / 2.9km		Average flight line length: 1.8mile / 2.9km
Median flight line length: 1.8mile / 2.9km		Median flight line length: 1.8mile / 2.9km
Maximum flight line length: 2.1mile / 3.4km		Maximum flight line length: 2.2mile / 3.5km
Minimum flight line length: 1.5mile / 2.4km		Minimum flight line length: 1.5mile / 2.4km
Estimated data size (128 bands, 1.5m): 10GB		Estimated data size (128 bands, 2.0m): 6GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T2.evf		E:\Oyster\Vectors\T2.evf
Total flight lines: 9		Total flight lines: 7
Total imaging distance: 19mile / 30km		Total imaging distance: 15mile / 24km
Average flight line length: 2.1mile / 3.4km		Average flight line length: 2.2mile / 3.5km
Median flight line length: 2.1mile / 3.4km		Median flight line length: 2.2mile / 3.5km
Maximum flight line length: 2.2mile / 3.6km		Maximum flight line length: 2.2mile / 3.6km
Minimum flight line length: 2.0mile / 3.3km		Minimum flight line length: 2.1mile / 3.3km
Estimated data size (128 bands, 1.5m): 5GB		Estimated data size (128 bands, 2.0m): 2GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T3.evf		E:\Oyster\Vectors\T3.evf
Total flight lines: 16		Total flight lines: 13
Total imaging distance: 42mile / 68km		Total imaging distance: 35mile / 56km
Average flight line length: 2.7mile / 4.3km		Average flight line length: 2.7mile / 4.3km
Median flight line length: 2.9mile / 4.6km		Median flight line length: 3.0mile / 4.8km
Maximum flight line length: 3.6mile / 5.7km		Maximum flight line length: 3.9mile / 6.2km
Minimum flight line length: 0.9mile / 1.4km		Minimum flight line length: 1.1mile / 1.8km
Estimated data size (128 bands, 1.5m): 11GB		Estimated data size (128 bands, 2.0m): 6GB

Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T4.evf		E:\Oyster\Vectors\T4.evf
Total flight lines: 13		Total flight lines: 2
Total imaging distance: 22mile / 35km		Total imaging distance: 16mile / 27km
Average flight line length: 1.7mile / 2.7km		Average flight line length: 8.4mile / 13.6km
Median flight line length: 1.7mile / 2.8km		Median flight line length: 8.7mile / 14.0km
Maximum flight line length: 1.8mile / 2.9km		Maximum flight line length: 8.7mile / 14.0km
Minimum flight line length: 1.2mile / 2.0km		Minimum flight line length: 8.2mile / 13.1km
Estimated data size (128 bands, 1.5m): 5GB		Estimated data size (128 bands, 2.0m): 3GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T5.evf		E:\Oyster\Vectors\T5.evf
Total flight lines: 3		Total flight lines: 4
Total imaging distance: 8mile / 13km		Total imaging distance: 7mile / 12km
Average flight line length: 2.8mile / 4.5km		Average flight line length: 2.0mile / 3.2km
Median flight line length: 2.8mile / 4.5km		Median flight line length: 2.2mile / 3.5km
Maximum flight line length: 3.0mile / 4.8km		Maximum flight line length: 2.5mile / 4.0km
Minimum flight line length: 2.6mile / 4.2km		Minimum flight line length: 1.5mile / 2.5km
Estimated data size (128 bands, 1.5m): 2GB		Estimated data size (128 bands, 2.0m): 1GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T6.evf		E:\Oyster\Vectors\T6.evf
Total flight lines: 27		Total flight lines: 21
Total imaging distance: 68mile / 110km		Total imaging distance: 54mile / 87km
Average flight line length: 2.5mile / 4.1km		Average flight line length: 2.6mile / 4.2km
Median flight line length: 2.7mile / 4.4km		Median flight line length: 2.8mile / 4.5km
Maximum flight line length: 3.7mile / 6.0km		Maximum flight line length: 3.4mile / 5.4km
Minimum flight line length: 1.3mile / 2.1km		Minimum flight line length: 1.1mile / 1.7km
Estimated data size (128 bands, 1.5m): 17GB		Estimated data size (128 bands, 2.0m): 10GB
Individual flight line length:		Individual flight line length:

E:\Oyster\Vectors\T7.evf		E:\Oyster\Vectors\T7.evf
Total flight lines: 10		Total flight lines: 2
Total imaging distance: 18mile / 29km		Total imaging distance: 12mile / 20km
Average flight line length: 1.8mile / 2.9km		Average flight line length: 6.4mile / 10.3km
Median flight line length: 1.8mile / 3.0km		Median flight line length: 6.6mile / 10.6km
Maximum flight line length: 2.2mile / 3.5km		Maximum flight line length: 6.6mile / 10.6km
Minimum flight line length: 1.5mile / 2.5km		Minimum flight line length: 6.2mile / 9.9km
Estimated data size (128 bands, 1.5m): 4GB		Estimated data size (128 bands, 2.0m): 2GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T8.evf		E:\Oyster\Vectors\T8.evf
Total flight lines: 17		Total flight lines: 13
Total imaging distance: 44mile / 71km		Total imaging distance: 35mile / 56km
Average flight line length: 2.6mile / 4.2km		Average flight line length: 2.7mile / 4.3km
Median flight line length: 2.6mile / 4.3km		Median flight line length: 2.7mile / 4.4km
Maximum flight line length: 3.1mile / 5.0km		Maximum flight line length: 3.1mile / 5.1km
Minimum flight line length: 1.8mile / 3.0km		Minimum flight line length: 2.1mile / 3.4km
Estimated data size (128 bands, 1.5m): 11GB		Estimated data size (128 bands, 2.0m): 6GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T9.evf		E:\Oyster\Vectors\T9.evf
Total flight lines: 5		Total flight lines: 4
Total imaging distance: 9mile / 15km		Total imaging distance: 7mile / 12km
Average flight line length: 1.9mile / 3.1km		Average flight line length: 1.9mile / 3.1km
Median flight line length: 2.0mile / 3.2km		Median flight line length: 2.1mile / 3.4km
Maximum flight line length: 2.2mile / 3.6km		Maximum flight line length: 2.2mile / 3.5km
Minimum flight line length: 1.4mile / 2.3km		Minimum flight line length: 1.5mile / 2.4km
Estimated data size (128 bands, 1.5m): 2GB		Estimated data size (128 bands, 2.0m): 1GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T10.evf		E:\Oyster\Vectors\T10.evf
Total flight lines: 21		Total flight lines: 14

Total imaging distance: 54mile / 87km		Total imaging distance: 42mile / 67km
Average flight line length: 2.6mile / 4.1km		Average flight line length: 3.0mile / 4.9km
Median flight line length: 2.6mile / 4.2km		Median flight line length: 2.8mile / 4.5km
Maximum flight line length: 3.9mile / 6.3km		Maximum flight line length: 4.9mile / 8.0km
Minimum flight line length: 1.0mile / 1.6km		Minimum flight line length: 1.4mile / 2.2km
Estimated data size (128 bands, 1.5m): 14GB		Estimated data size (128 bands, 2.0m): 8GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T11.evf		E:\Oyster\Vectors\T11.evf
Total flight lines: 26		Total flight lines: 20
Total imaging distance: 109mile / 175km		Total imaging distance: 84mile / 135km
Average flight line length: 4.2mile / 6.8km		Average flight line length: 4.2mile / 6.8km
Median flight line length: 3.3mile / 5.3km		Median flight line length: 3.3mile / 5.3km
Maximum flight line length: 7.6mile / 12.2km		Maximum flight line length: 6.9mile / 11.1km
Minimum flight line length: 0.9mile / 1.4km		Minimum flight line length: 1.4mile / 2.3km
Estimated data size (128 bands, 1.5m): 28GB		Estimated data size (128 bands, 2.0m): 16GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T12.evf		E:\Oyster\Vectors\T12.evf
Total flight lines: 9		Total flight lines: 8
Total imaging distance: 28mile / 46km		Total imaging distance: 22mile / 36km
Average flight line length: 3.2mile / 5.2km		Average flight line length: 2.8mile / 4.6km
Median flight line length: 3.2mile / 5.2km		Median flight line length: 2.9mile / 4.6km
Maximum flight line length: 3.6mile / 5.7km		Maximum flight line length: 3.6mile / 5.8km
Minimum flight line length: 2.8mile / 4.6km		Minimum flight line length: 1.9mile / 3.1km
Estimated data size (128 bands, 1.5m): 7GB		Estimated data size (128 bands, 2.0m): 4GB
Individual flight line length:		Individual flight line length:
E:\Oyster\Vectors\T13.evf		E:\Oyster\Vectors\T13.evf
Total flight lines: 29		Total flight lines: 22
Total imaging distance: 137mile /		Total imaging distance: 106mile /

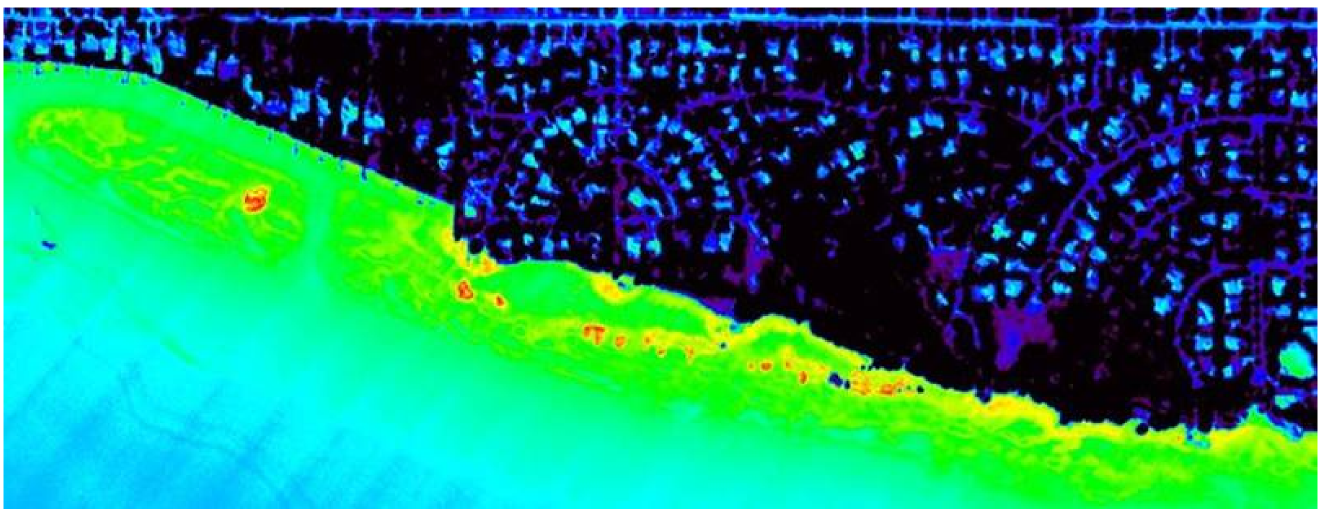
221km		171km
Average flight line length: 4.7mile / 7.6km		Average flight line length: 4.8mile / 7.8km
Median flight line length: 5.2mile / 8.4km		Median flight line length: 5.4mile / 8.7km
Maximum flight line length: 7.1mile / 11.4km		Maximum flight line length: 7.2mile / 11.7km
Minimum flight line length: 1.3mile / 2.1km		Minimum flight line length: 1.4mile / 2.3km
Estimated data size (128 bands, 1.5m): 36GB		Estimated data size (128 bands, 2.0m): 20GB
Individual flight line length:		Individual flight line length:
597 miles		**465 miles**
152 GB		**85 GB**

Attachment 2

Example 1
Hyperspectral Imagery
(True Color)

Example 2
Hyperspectral Imagery
(Color InfraRed)

Example 3
Hyperspectral Imagery
(False Color)



Attachment 3: Metadata

Applied Hyperspectral Imaging Services

Galileo GROUP, INC.

Hyperspectral Oyster Bed Mapping of Tampa Bay

DATA MANUAL

1. GIS Layer

Projection: Albers DOQQ, meter, NAD83

NEPTUNE II_Oyster Bed_Sites.shp:

- Each mapped oyster bed site is represented by a point
- SITE: oyster bed site number
- FLIGHT: flight number where the oyster bed is located
- SITE1: local site number within one flight

NEPTUNE II_Oyster Bed_Polygons.shp:

- The shape of each oyster bed is represented by one or more polygons
- POLYGON: ordered overall polygon number
- SITE: oyster bed site number
- POLYGON1: ordered polygon number within one site
- FLIGHT: flight number where the oyster bed is located

2. Radiance Data

Directory: Data\20050521\RAD; Data\20050523\RAD; …

File: 0521-0836_rad.dat & 0521-0836_rad_rgb.dat

- 0521: flight date (May 21, 2005)
- 0836: flight time (08:36 ET)
- _rgb: selected 3 bands data for natural color image

Flight Altitude: 6,600 Feet

Specification: check header file like 0521-0836_rad.hdr

Software: ENVI or ArcGIS with ENVI plug-in for simple processing. For spectral analysis, ENVI is highly recommended.

3. Mosaic Image

Directory: Mosaic

File: Neptune II_Mosaic.tif

Projection: UTM, N17, meter, NAD83 (same as the DOQQ ortho-photo used as reference)

Galileo Group, Inc. • 100 Rialto Place, Suite 737 • Melbourne, Florida 32901
Tel: 321.733.0960 • Fax: 888.283.0061 • Web: galileo-gp.com

4. Geographic Lookup Table (GLT) File

Directory: Data\20050521\GLT; Data\20050523\GLT; …

File: 0521-0836_glt_map.dat

- 0521: flight date (May 21, 2005)
- 0836: flight time (08:36 ET)

Function: Each radiance file has a GLT file. It is used to geo-rectify radiance data or any analysis results based on radiance data to the following projection. Geo-reference using GLT file is supported by ENVI, or other software (may or may not).

Projection: Albers DOQQ, meter, NAD83

Note: The GLT file is generated by Galileo Group for your convenience while the delivered shape and mosaic file are processed by proprietary software from the sensor manufacturer. The difference of these two is 1-2 pixels RMSE. There are also some artifacts in GLT results due to different resampling methods in processing.

Galileo Group, Inc. • 100 Rialto Place, Suite 737 • Melbourne, Florida 32901
Tel: 321.733.0960 • Fax: 888.283.0061 • Web: galileo-gp.com

GIS Metadata:

0811_NEPTUNE II_Oyster Bed_Polygons

Metadata:

- Identification Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Distribution_Information
- Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Publication_Date: Unpublished Material
Title: 0811_NEPTUNE II_Oyster Bed_Polygons
Geospatial_Data_Presentation_Form: vector digital data
Description:
Abstract:
This data set represents Hyperspectral Oyster Bed Mapping of Tampa Bay. The Galileo Group, Inc. flew the Tampa Bay coastline at low tide to collect the hyperspectral data as well as RGB photo imagery.
Purpose:
The objective of this mapping exercise was to establish a baseline map layer for the current extent of oysters within Tampa Bay. This effort provides the base data source for future mapping projects and enables trend analyses to be performed to aid scientists in their monitoring efforts. Hyperspectral imagery, comprising 128 spectral bands, was collected at low tide for the near shore of Tampa Bay, Boca Ciega and the Narrows. The flight was planned to correspond with the low tide cycle so that the intertidal areas of the Bay would be exposed. The Galileo Group flew the area and performed the hyperspectal analysis.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 9/15/2005
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -82.764659
East_Bounding_Coordinate: -82.383251
North_Bounding_Coordinate: 28.020282
South_Bounding_Coordinate: 27.569306
Keywords:
Theme:
Theme_Keyword: Hyperspectral
Theme_Keyword: Tampa Bay
Theme_Keyword: oyster

Theme_Keyword: oyster reefs
Theme_Keyword: oyster beds
Theme_Keyword: oyster clumps
Place:
Place_Keyword: Tampa Bay
Access_Constraints:
All data must be verified by Principal Investigator or Group Database Analyst prior to release. It is strongly recommended that this data is directly acquired from FWC and not indirectly through other sources which may have changed the data in some way. FWC makes no claims as to the data's suitability for other purposes.
Use_Constraints:
FWC-FWRI must be credited. This is not a survey data set and should not be utilized as such. These data are not to be used for navigation. Acknowledgement of the FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute) as the data source would be appreciated in any products developed from these data, and such acknowledgment as is standard for citation and legal practices for data source is expected by users of this data. Please cite the original metadata when using portions of the record to create a similar record of slightly altered data, such as reprojection. If any data are modified or adjusted, please share the edited information with FWC. Users should be aware that comparison with other data sets for the same area from other time periods may be inaccurate due to inconsistencies resulting from changes in mapping conventions, data collection, and computer processes over time. FWC shall not be liable for improper or incorrect use of this data. These data are not legal documents and are not to be used as such. This is not a survey data set and should not be utilized as such. These data are not to be used for navigation.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
Fish and Wildlife Research Institute 100 Eighth Avenue Southeast
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-5020
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Hours_of_Service: Monday – Friday 8:00 a.m.-5:00 p.m. Eastern time
Security_Information:
Security_Classification_System: FWRI-DC
Security_Classification: Available without restriction
Security_Handling_Description: Available without restriction
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: All entities and attributes have been identified.

Lineage:
Process_Step:
Process_Date: Unknown

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 1009

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 24.000000
Standard_Parallel: 31.500000
Longitude_of_Central_Meridian: -84.000000
Latitude_of_Projection_Origin: 24.000000
False_Easting: 400000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000128
Ordinate_Resolution: 0.000128
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: 0811_NEPTUNE II_Oyster Bed_Polygons
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.

Attribute:
Attribute_Label: POLYGON
Attribute_Definition: ordered overall polygon number
Attribute_Definition_Source: Derived from information provided by the Galileo Group
Attribute:
Attribute_Label: SITE
Attribute_Definition: oyster bed site number
Attribute_Definition_Source: Derived from information provided by the Galileo Group
Attribute:
Attribute_Label: POLYGON1
Attribute_Definition: ordered polygon number within one site
Attribute_Definition_Source: Derived from information provided by the Galileo Group
Attribute:
Attribute_Label: FLIGHT
Attribute_Definition: flight number where the oyster bed is located
Attribute_Definition_Source: Derived from information provided by the Galileo Group
Overview_Description:
Entity_and_Attribute_Overview:
This is a detailed description of the attributes for the 0811_NEPTUNE II_Oyster Bed_Polygons. These attributes were obtained from the Galileo Group, Inc. The shape of each oyster bed is represented by one or more polygons.

Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
Fish and Wildlife Research Institute 100 Eighth Avenue Southeast
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-5020
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Hours_of_Service: 8:00 a.m.-5:00 p.m. Eastern time
Resource_Description: Downloadable Data
Distribution_Liability:
This data set is in the public domain, and the recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a FWC-FWRI produced data set; it is provided “as-is” without warranty of any kind, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this data set for a specific application. In no event will the staff of the Fish and Wildlife Research Institute be liable for any damages, including lost profits, lost savings, or other incidental or consequential damages arising from the use of or the inability to use this data set.
Standard_Order_Process:

Non-digital_Form:
Contact GIS Librarian by e-mail, telephone, or letter explaining which products are needed and providing a brief description of how the products will be used. Also, provide name and address of the person or organization requesting the products
Fees:
None. However, persons or organizations requesting information must provide transfer media (CD-ROM only) if FTP is not available and must pay express shipping costs if express shipping is required.
Ordering_Instructions:
Contact GIS Librarian by e-mail, telephone, or letter explaining which products are needed and providing a brief description of how the products will be used. Also, provide name and address of the person or organization requesting the products.
Turnaround:
Usually within 10 business days, although, complex requests may take longer
Custom_Order_Process: Contact GIS Librarian
Available_Time_Period:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2/14/2006

Metadata_Reference_Information:
Metadata_Date: 20060213
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
Fish and Wildlife Research Institute 100 Eighth Avenue Southeast
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-5020
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Hours_of_Service: 8:00 a.m.-5:00 p.m. Eastern time
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: No restrictions on metadata.
Metadata_Use_Constraints: Metadata must be distributed with the data set
Metadata_Security_Information:
Metadata_Security_Classification_System: FWRI-MC
Metadata_Security_Classification: Available
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

FWRI_TB_oysters

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Distribution_Information
- Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Originator: FWC-FWRI
Publication_Date: Unpublished Material
Publication_Time: 2/14/2006
Title: FA_4_PI
Geospatial_Data_Presentation_Form: vector digital data
Description:
Abstract:
This data set represents oyster reef coverage around Tampa Bay. A combination of methodologies was employed on 2005 low tide true color imagery provided by the Galileo Group, Inc. Visual Learning Systems software, Feature Analyst and photo interperation was used to assertain oyster reef coverage in the Bay area.
Purpose:
The objective of this mapping exercise was to establish a baseline map layer for the current extent of oysters within Tampa Bay. This effort provides the base data source for future mapping projects and enables trend analyses to be performed to aid scientists in their monitoring efforts.
Supplemental_Information:
Prior to July 1, 2004, the Fish and Wildlife Research Institute (FWRI) was known as the Florida Marine Research Institute (FMRI). The institute name has not been changed in historical data sets or references to work completed by the Florida Marine Research Institute. The institute name has been changed in references to ongoing research, new research, and contact information.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2/14/2006
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -82.846493
East_Bounding_Coordinate: -82.385410
North_Bounding_Coordinate: 28.023691
South_Bounding_Coordinate: 27.581787
Keywords:

Theme:
Theme_Keyword: oysters
Theme_Keyword: Tampa Bay
Theme_Keyword: oyster reef mapping
Theme_Keyword: oyster reef
Theme_Keyword: oyster clumps
Theme_Keyword: mangrove root oyster
Theme_Keyword: low tide imagery
Place:
Place_Keyword: Tampa Bay
Access_Constraints:
All data must be verified by Principal Investigator or Group Database Analyst prior to release. It is strongly recommended that this data is directly acquired from FWC and not indirectly through other sources which may have changed the data in some way. FWC makes no claims as to the data's suitability for other purposes.
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Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
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City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-5020
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Security_Information:
Security_Classification_System: FWRI-DC
Security_Classification: Available without restriction
Security_Handling_Description: Available without restriction
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Attributes are accurate as the source data.
Logical_Consistency_Report: These data are logically consistent.
Completeness_Report: These data are complete for the state of Florida
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Positional accuracy has not been determined and varies according to linework source.
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Galileo Group, Inc.
Publication_Date: Unpublished Material
Title: NeptuneII_mosaic
Geospatial_Data_Presentation_Form: raster digital data
Source_Scale_Denominator: 6600
Type_of_Source_Media: Digital imagery
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 29/2005
Source_Currentness_Reference: ground condition
Source_Contribution:
Low tide imagery was use for photo interperation of oyster reefs in Tampa Bay
Process_Step:
Process_Description:
Oyster reefs were produced by "heads up" digitizing using the 2005 imagery provided by the Galileo Group, Inc. of Tampa Bay. In specific cases, 2004 digital ortho-photography were used.
Process_Date: 2005
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
Fish and Wildlife Research Institute 100 Eighth Avenue Southeast
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-2050
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Hours_of_Service: 8:00 a.m.-5:00 p.m. Eastern time

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
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Latitude_of_Projection_Origin: 0.000000
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False_Northing: 0.000000
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Coordinate_Representation:
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Ellipsoid_Name: Geodetic Reference System 80
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Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:

Attribute_Label: CLASS_ID
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Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Data Librarian
Contact_Organization:
FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)
Contact_Position: GIS Data Librarian
Contact_Address:
Address_Type: mailing and physical address
Address:
Fish and Wildlife Research Institute 100 Eighth Avenue Southeast
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33701-5020
Country: USA
Contact_Voice_Telephone: 727-896-8626
Contact_Facsimile_Telephone: 727-893-1679
Contact_Electronic_Mail_Address: GISLibrarian@MyFWC.com
Hours_of_Service: 8:00 a.m.-5:00 p.m. Eastern time
Resource_Description: Downloadable Data
Distribution_Liability:
This data set is in the public domain, and the recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a FWC-FWRI produced data set; it is provided “as-is” without warranty of any kind, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this data set for a specific application. In no event will the staff of the Fish and Wildlife Research Institute be liable for any damages, including lost profits, lost savings, or other incidental or consequential damages arising from the use of or the inability to use this data set.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.554

Fees:
None. However, persons or organizations requesting information must provide transfer media if FTP is not available and must pay express shipping costs if express shipping is required.
Ordering_Instructions:
Contact GIS Librarian by e-mail, telephone, or letter explaining which products are needed and providing a brief description of how the products will be used. Also, provide name and address of the person or organization requesting the products.
Turnaround:
Usually within 10 business days, although, complex requests may take longer
Available_Time_Period:
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Calendar_Date: 2/14/2006

Metadata_Reference_Information:
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Contact_Position: GIS Data Librarian
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Address:
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City: St. Petersburg
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Metadata_Extensions:
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Attachment 4: Galileo Technical Report

GROUP, INC.

Hyperspectral Oyster Mapping in Tampa Bay Area

Technical Report

24 May 2006

1. Airborne Hyperspectral Imaging

As specified in the statement of work, the AISA Eagle sensor was configured to collect hyperspectral data with 128 bands and a Ground Sample Distance (GSD) of 1.5 meter. A total of 155 flight lines were collected to cover all areas. Among them, 19 flight lines were redundant ones and were excluded from data processing and analysis. All other 136 flight lines were radiometrically calibrated to radiance data, and normalized to compensate solar irradiance variations. The calibrated data were then geo-rectified using the correspondent GPS and IMU information. Further geo-referencing was applied using the 2004 Digital Orthographic Quarter-Quad http://data.labins.org/2003/MappingData/DOQQ/doqq_04_utm.cfm) as the reference and all individual flight lines were stitched together. The final mosaic images were presented in UTM N17 projection with the datum of NAD83, and the spatial resolution is 1.5 by 1.5 m. Figure 1 shows the natural color mosaic image of the whole coverage, with band 55 (641 nm) as red, band 36 (552 nm) as green and band 16 (461 nm) as blue.

Figure 1 Natural color mosaic images of all region of interest

For optimal imaging quality, all flight missions were conducted in the morning and afternoon solar window when the sun elevation angles were between 30 and 45 degrees, in order to avoid solar glint and maintain good signal at the same time. For the majority of all flight lines between May 21 and May 23, 2005, the chosen solar window overlapped with daily low tide window. The remaining flight lines were finished on May 27 due to weather delay. For these flight lines, the same solar window was maintained but the tides were higher than previous days. The adverse effects due to high tides will be discussed in following sections.

2. Ground Truthing

There were two field ground truthing missions conducted by Galileo personnel and Fish and Wildlife Research Institute (FWRI). During the first trip on May 5, an oyster bed in side Pinellas National Wildlife Refuge (near the old bridge) was located and delineated using Trimble GPS unit. This oyster bed was accurately located on hyperspectral images using recorded GPS data. A couple of other oyster beds were also located south of Pinellas Peninsula (Pinellas Point). However, these oyster beds were not properly delineated using GPS and the corresponding region on hyperspectral image was not clearly defined thus no spectral signature was extracted.

Figure 2 Example of geo-tagged FWRI helicopter survey photo

In stead, a few more oyster beds were identified and delineated in hyperspectral images by the help of previous helicopter survey photos taken by FWRI. These photos have tags with GPS recorded coordinates as shown in Figure 2. Using the tagged geo-coordinates and ancillary information in the photo (like relative position of the three oyster beds, array of boats on the left side), the corresponding oyster beds were located in hyperspectral images as shown in Figure 3. Once the oyster beds were delineated in hyperspectral images, the spectral signature for each oyster site was extracted after excluding spectrally abnormal pixels. There were four spectral signatures extracted for the first round analysis and the initial results were used to plan the second ground truthing trip.

Figure 3 Oyster beds delineated in hyperspectral images corresponding to aerial photos

For the second ground truthing on June 24, close to 10 oyster beds were verified positively based on the initial result. A few other oyster beds were validated near Green Key. This is the area when the data were collected on May 27 when the tide was relatively high. One of the verified oyster beds was then used to extract the fifth spectral signature. The third planned site near Cockroach Bay turned out unsuccessful as the tide was at its highest.

3. Data Analysis

The basic spectral mapping method applied to map oyster beds from the processed hyperspectral images is Spectral Angular Mapping (SAM). The SAM method compares two spectra by calculating the angular distance between the two vectors. For the classification, all pixels in the scene are compared with the signature spectra that were extracted from known oyster beds pixels. For the second round mapping, five spectral signatures were used in total. These five spectra consider variations in oyster bed type, tidal condition and imaging time (morning or afternoon).

Before SAM calculation, the optimal set of bands was selected to maximize the distance between the target signature and background pixels. The BANDMAX algorithm in ENVI (BANDMAX is developed by Galileo Group and licensed to RSI for use in ENVI) was used to select the bands. For this project specifically, the target is oyster bed and the background is sand mixed with algae. A group of 76 bands were selected from 128 bands in total.

After SAM calculation, the oyster beds were mapped automatically based on SAM value. That is, for all pixels with SAM value below certain threshold were selected. To prevent false positives being selected, all pixels over land were masked (excluded), and small isolated pixels were filtered out using low pass filters. For final fine tuning of the results, the threshold values were adjusted dynamically based on the background (mainly caused by tidal variation) and the mapped oyster beds were visually validated using the natural color image. The visual validation was used to exclude some false positives based on ancillary information (for example, if the mapped site is too far off shore). For the last step, the mapped pixels were transformed to shape files for delivery.

4. Accuracy Evaluation

Before evaluation, a few terms are to be defined. **True Positive** is oyster point verified on ground and mapped (hyperspectral, or photo interpretation); **False Negative** is oyster point on ground but not mapped; **True Negative** is non-oyster point verified on ground and not mapped; **False Positive** is non-oyster point verified on ground and but mapped. Using these four terms, we define two properties to evaluate the mapping accuracy: **Sensitivity** = True Positives/(True Positives + False Negatives), and **Positive Predictive Value** = True Positive/(True Positive + False Positive). This first one shows the percentage of correctly mapped oyster points against ground truth, while the second one shows the ratio between correct mapping and false positive.

To evaluate the accuracy, the photo-interpreted results by FWRI were used as the reference which is believed to have 78% accuracy overall. For accurate assessment, all points not covered by hyperspectral images (Cross Bayou) were excluded from this analysis. There are 1131 oyster points and 391 non-oyster ones in total.

For sensitivity analysis, Figure 4 shows the sensitivity comparison of photo-interpretation and hyperspectral mapping. The X-axis is the size of the buffer (the maximum distance from know target to mapped target to claim positive hit), from 0m to 20m. The buffer is used to accommodate GPS error and geo-accuracy in hyperspectral images. It also accommodates the underestimation in hyperspectral delineation in terms of size of the oyster bed. From Figure 4 we can see that, by enlarging the buffer zone, the sensitivities converge quickly thus making it a reasonable indicator. In this case, the FWRI method converges to 100% while the Galileo method converges to 60%. (Using a fixed 5m, these numbers would be 95% and 46% respectively).

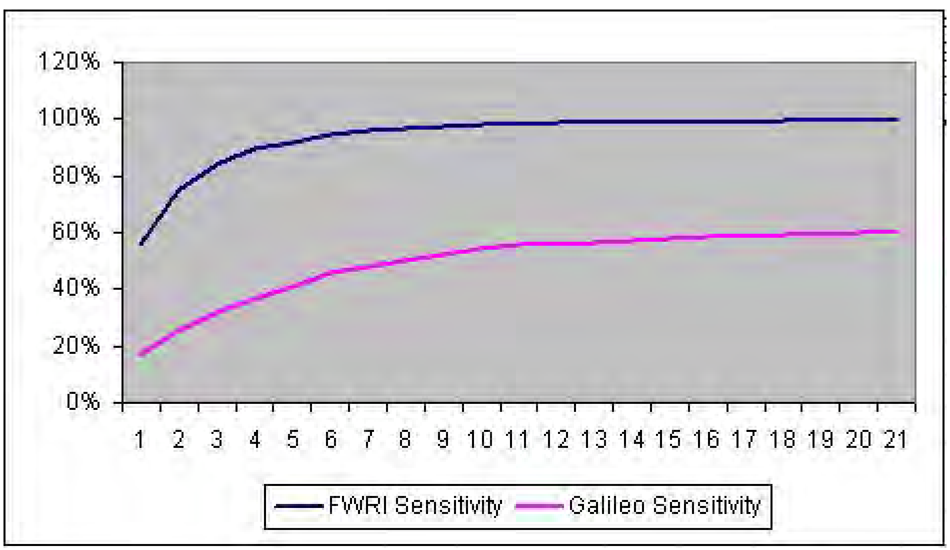


Figure 4 Sensitivity comparison between FWRI and Galileo mapping

For the 100% FWRI sensitivity, it shows that the photo-interpretation method locates all oyster beds. However, this figure is somewhat inflated as almost all ground verification sites are extracted from the mapped sites of photo-interpretation method.

For the Positive Predictive Value analysis, we also use the variable buffer zone method. From Figure 5 we can see that the FWRI value converges to 82% while the Galileo one is 71%. In other words, for every 8 mapped oyster points using photo-interpretation, there are 2 false positives. For hyperspectral, it's 7 by 3. However, both numbers are underestimated due to the selection of non-oyster points. For many of the non-oyster points, they are right next to the oyster points (around 5m). Given the buffer zone, these points will likely be counted as False Positives. In other words, these values reflect the accuracy of oyster bed delineation rather than the false positive ratio in terms of overall oyster bed presence.

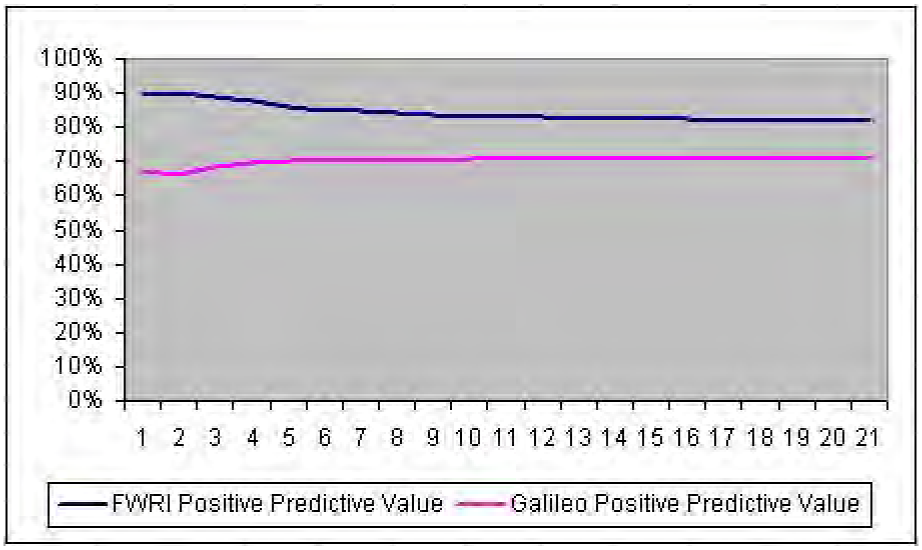


Figure 5 Positive Predictive Value comparison between FWRI and Galileo mapping

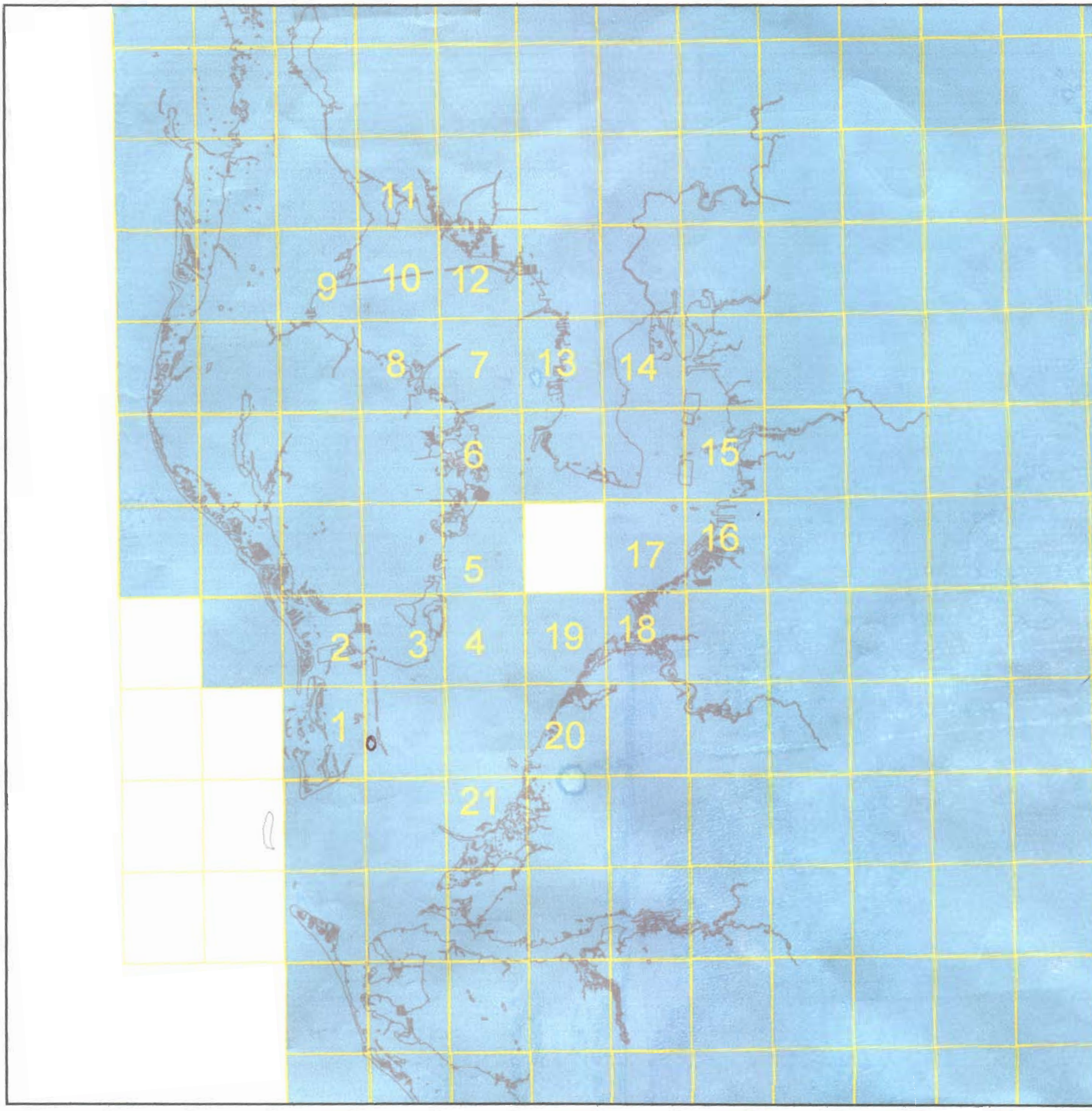
5. Conclusion and Discussion

From the evaluation in last section, we can see that the hyperspectral mapping method produces around 60% sensitivity. That is, 6 out of the 10 oyster bed presences were mapped (for presence, it means the accuracy in terms of size is ignored). It is also concluded that the main concern is omission, that 40% of the oyster beds were not found. By detail examination, most of the missed ones are fringe reefs. To improve the hyperspectral method, a few key modifications and additions are suggested to be applied to the data processing and analysis algorithms:

- Incorporate photo-interpretation techniques with spectral mapping, mainly the spatial information like shape and size
- Utilize ancillary information like bathymetry data
- New spectral mapping method like matched filtering
- Atmospheric correction to correct variation in solar irradiance
- Water column compensation to correct variation

Attachment 5: Field Reconnaissance Notes plotted on aerial images

Green boundaries indicate area targeted fro field review. Oysters actually observed in field noted in dark ink. When scanned, some of these notes are obscured. Comments have been inserted where appropriate to aid in deciphering these.



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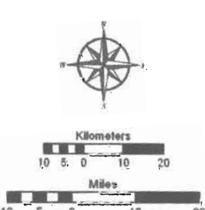

Main

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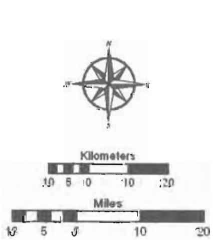

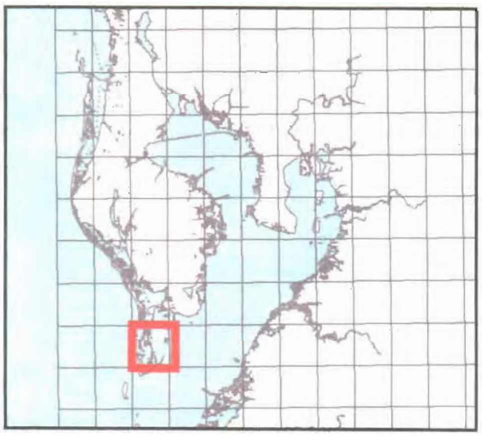

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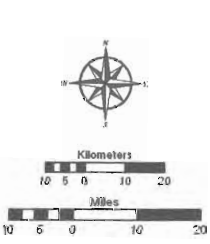

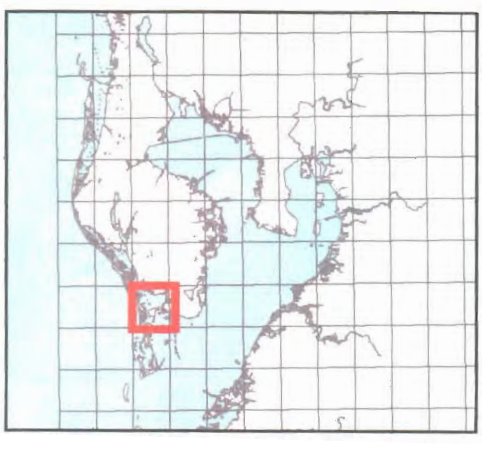

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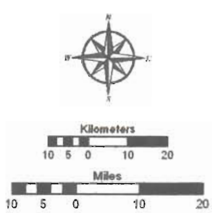

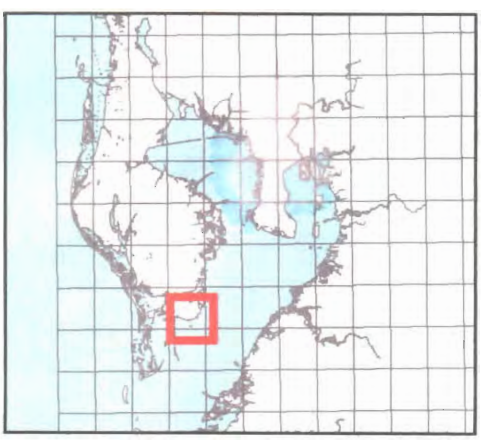

Map 3

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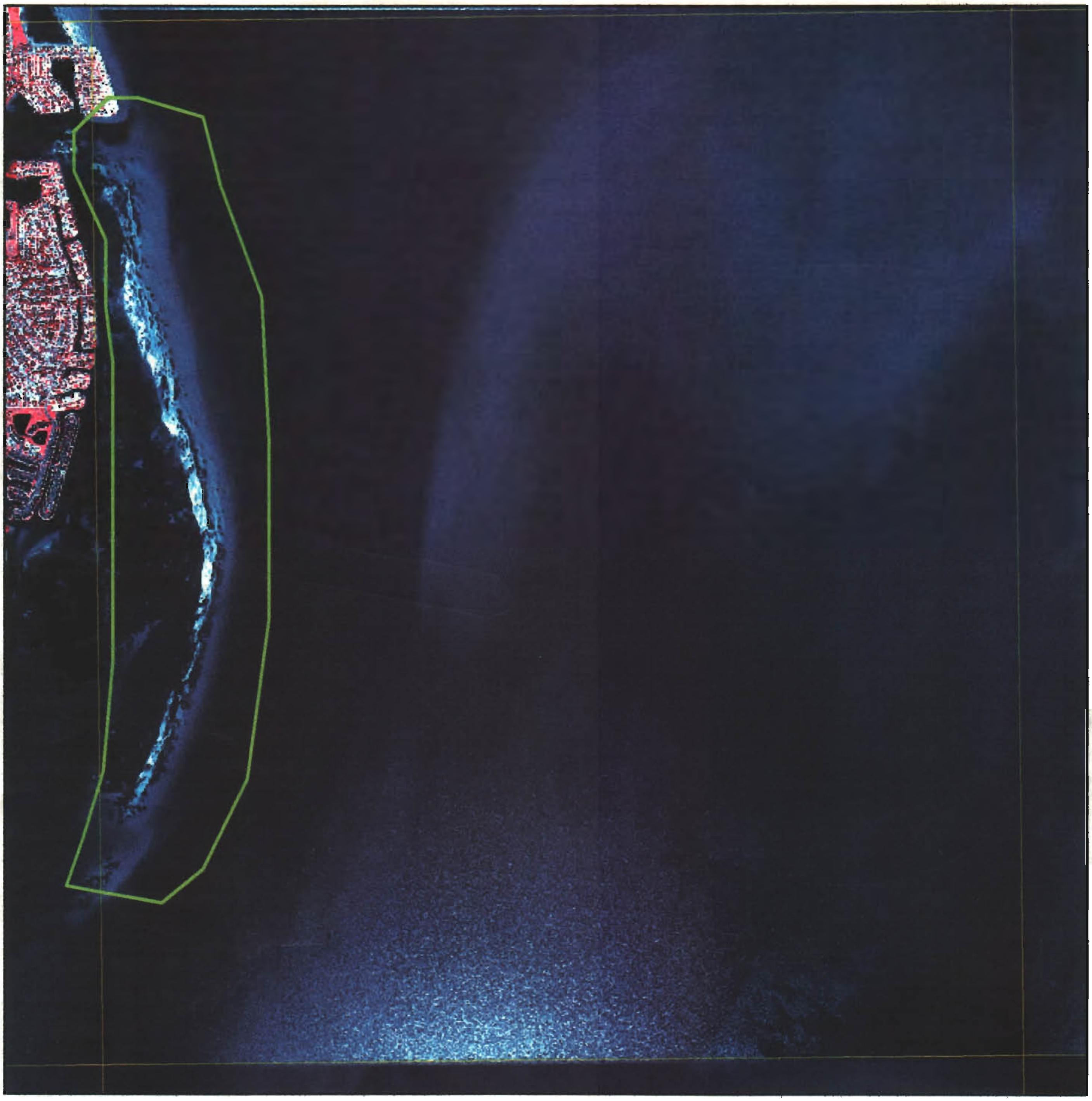

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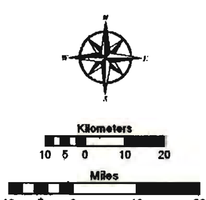

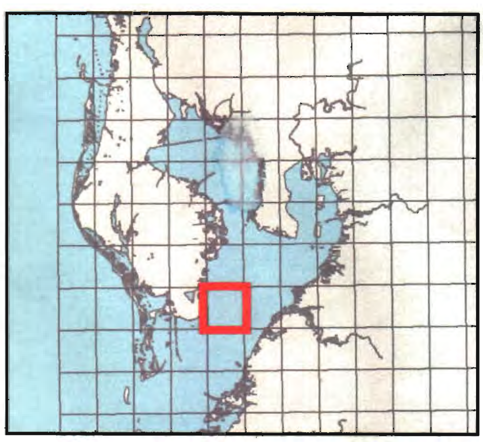

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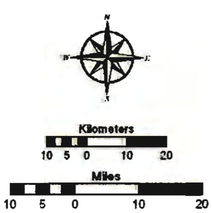
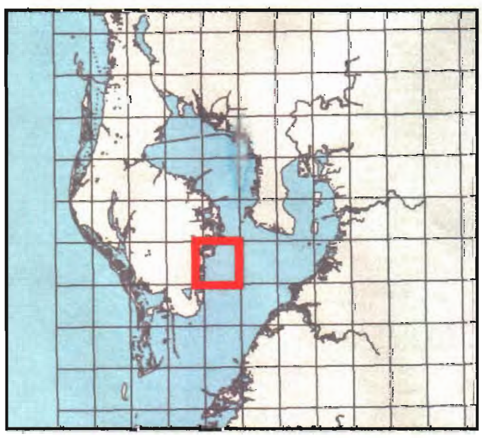
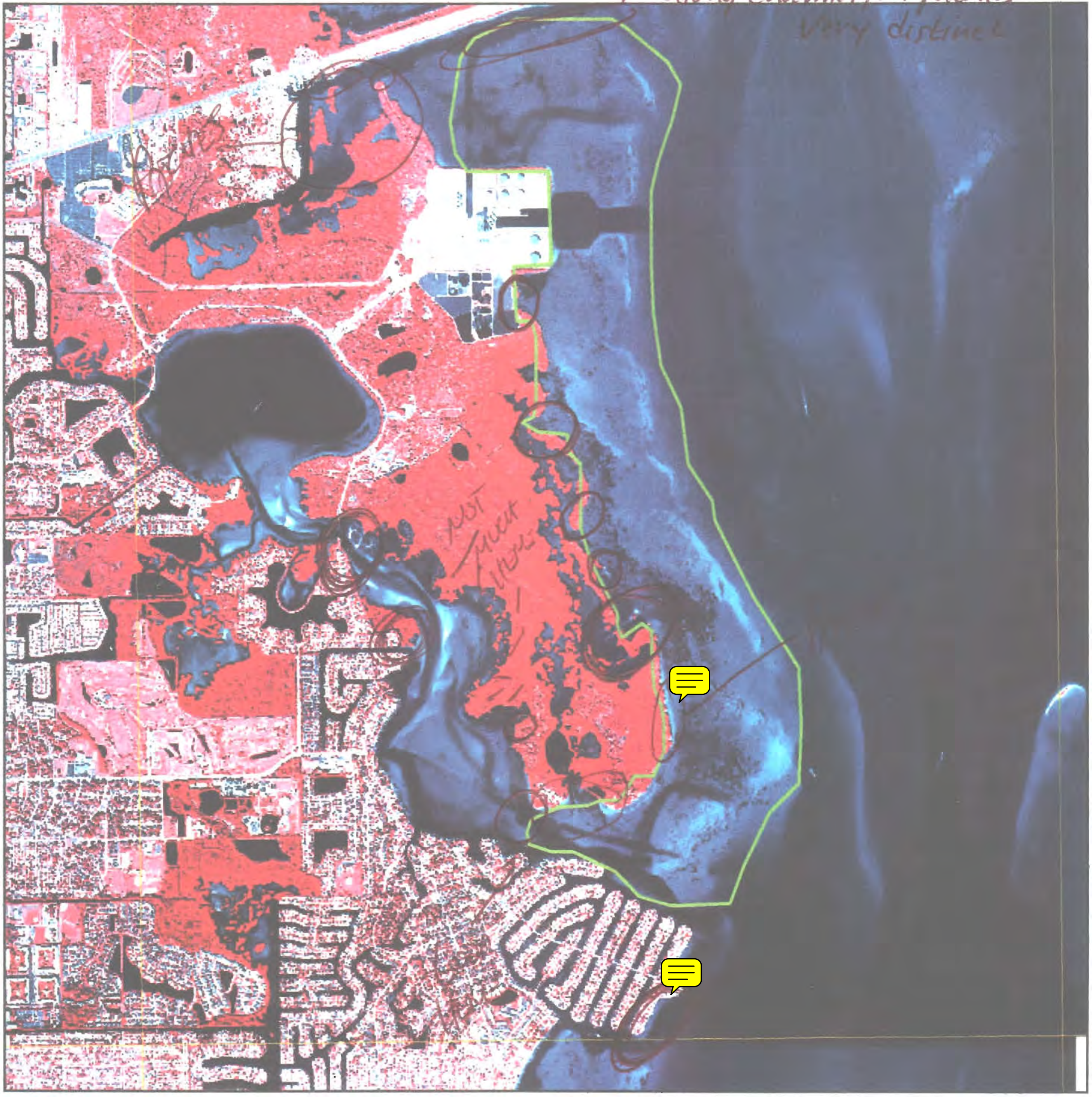




Map 5

along channel, in patches
Very distinct



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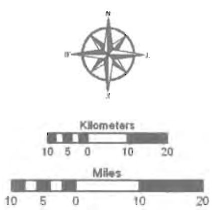

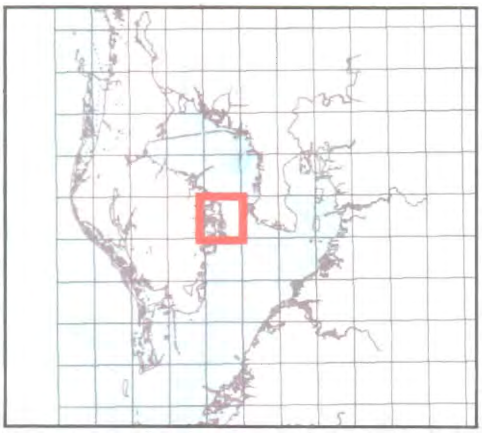

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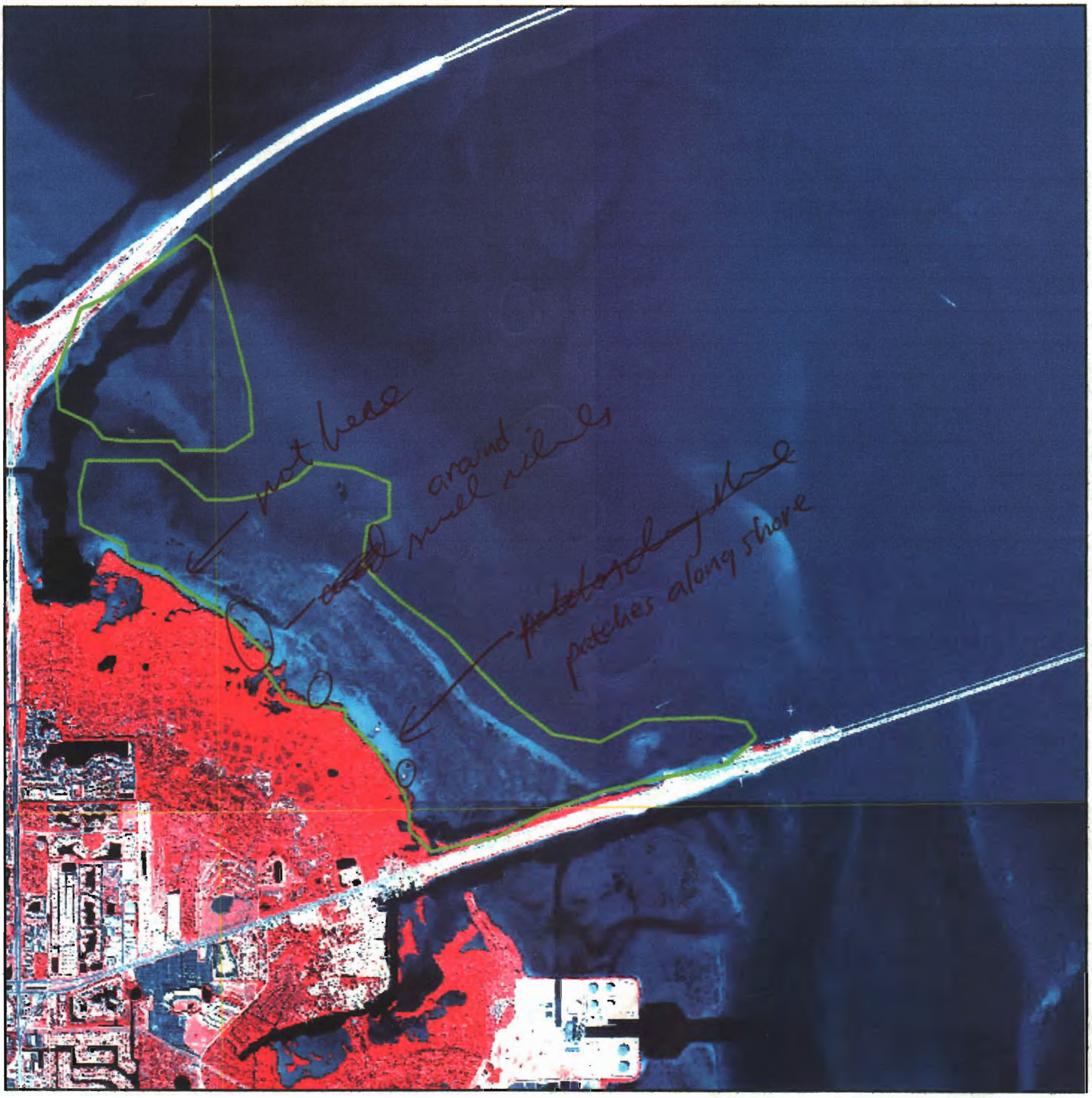

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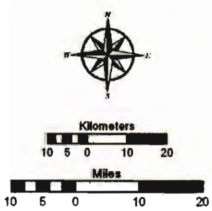

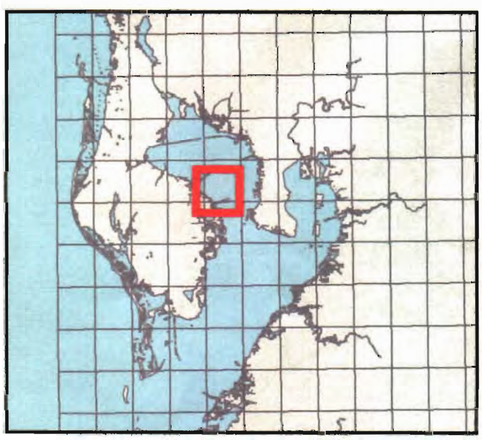

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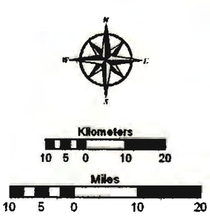

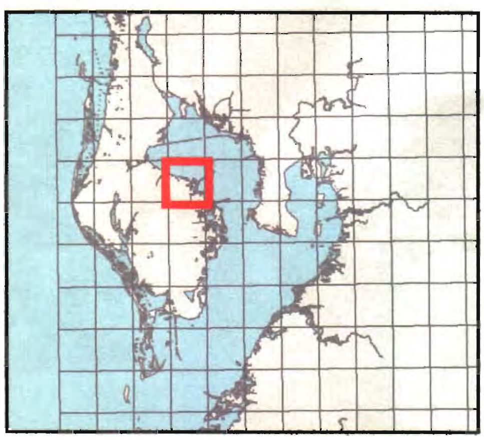

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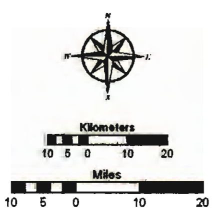

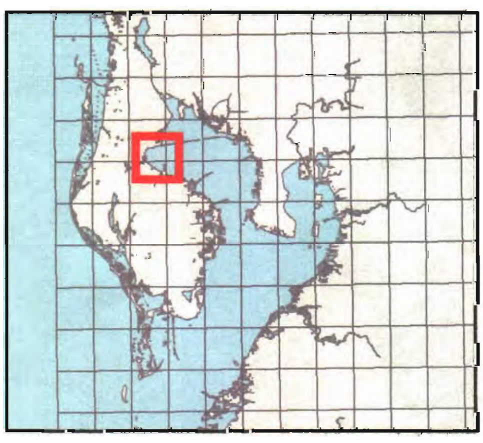

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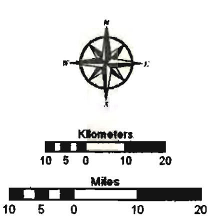
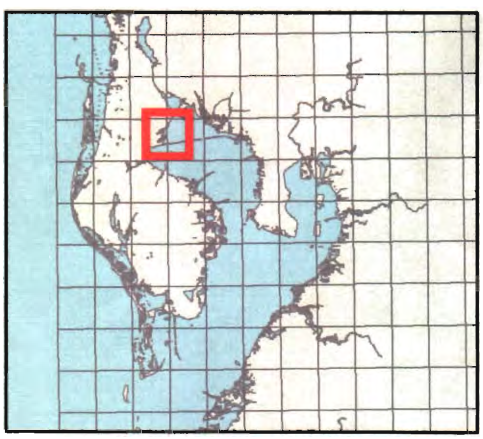




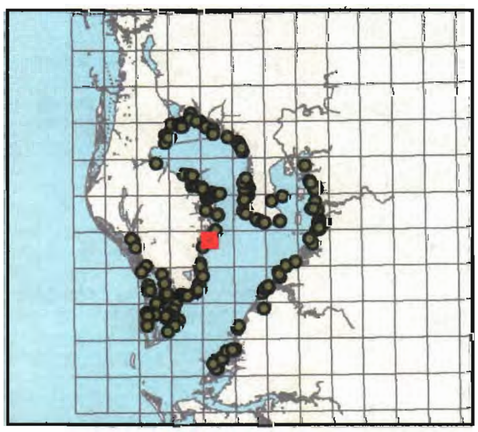
Map 10

Oyster Mapping

Snell Island

Meters

170 85 0 170



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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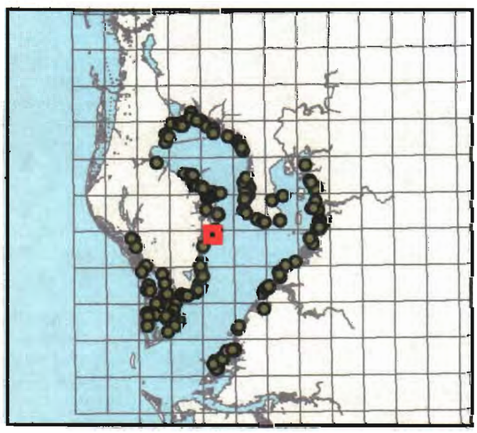
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Shore Acres

Meters

210 105 0 210



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

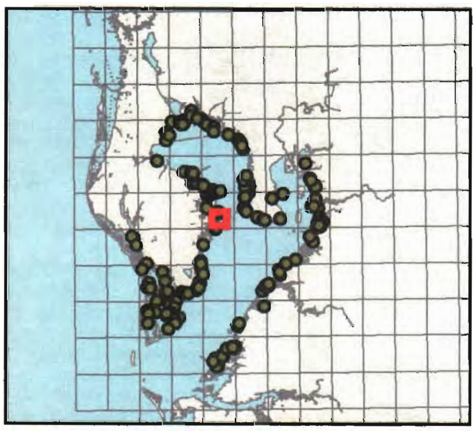
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Weedon Island

Meters

250 125 0 250



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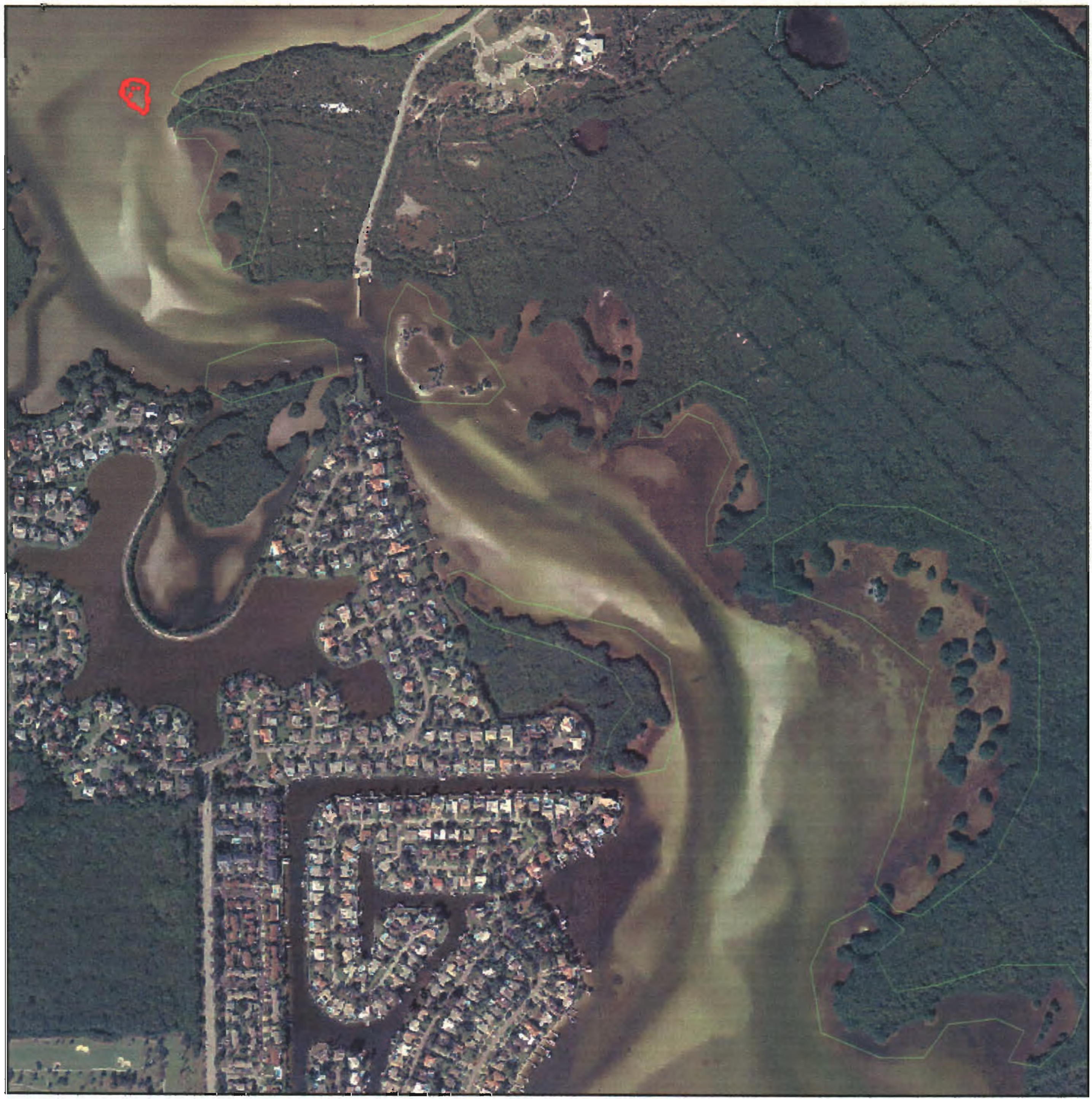

Oyster Mapping

Weedon Island

Fringing_reefs

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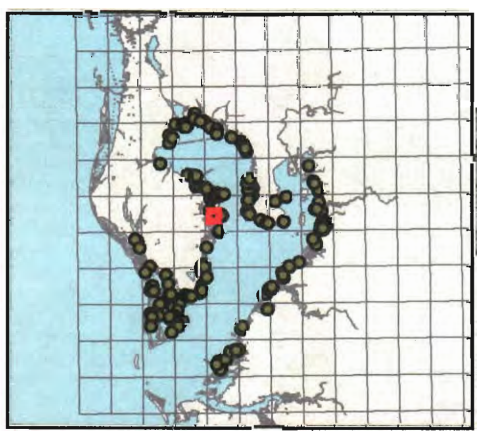

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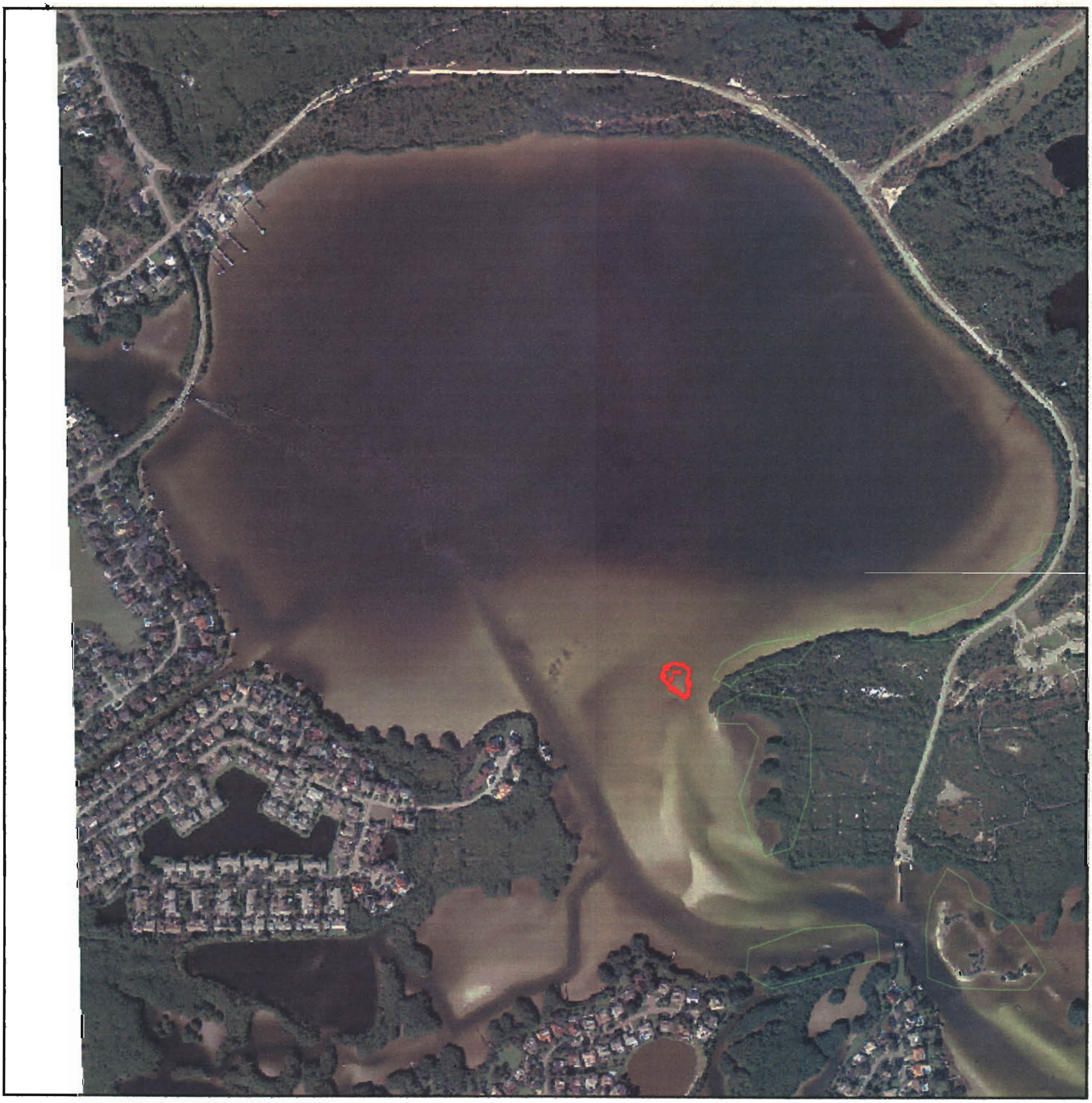

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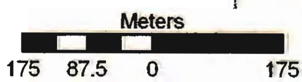

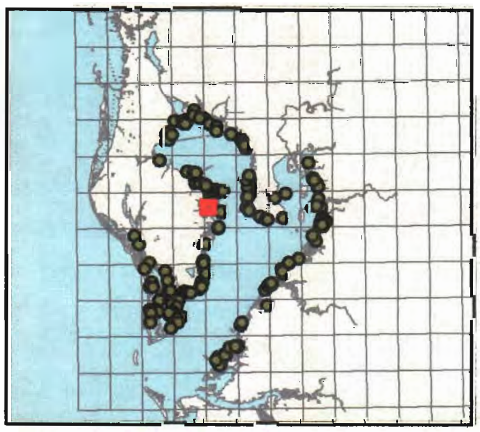

Weedon Island
Riviera Bay

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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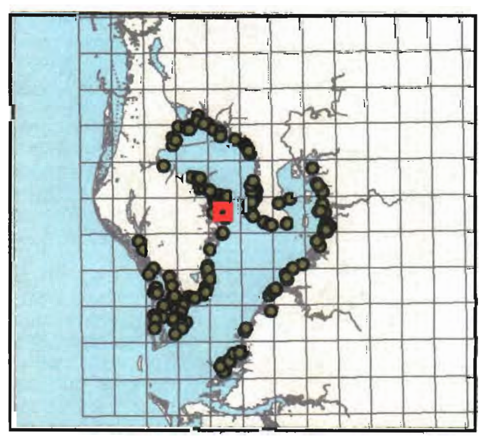
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Weedon Island

Meters

220 110 0 220



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

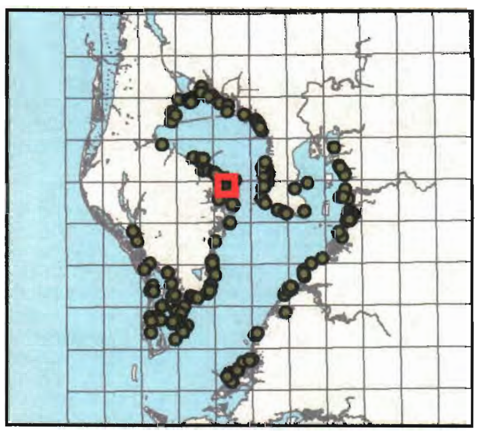
Oyster Mapping

North of Weedon Island
Snug Harbor

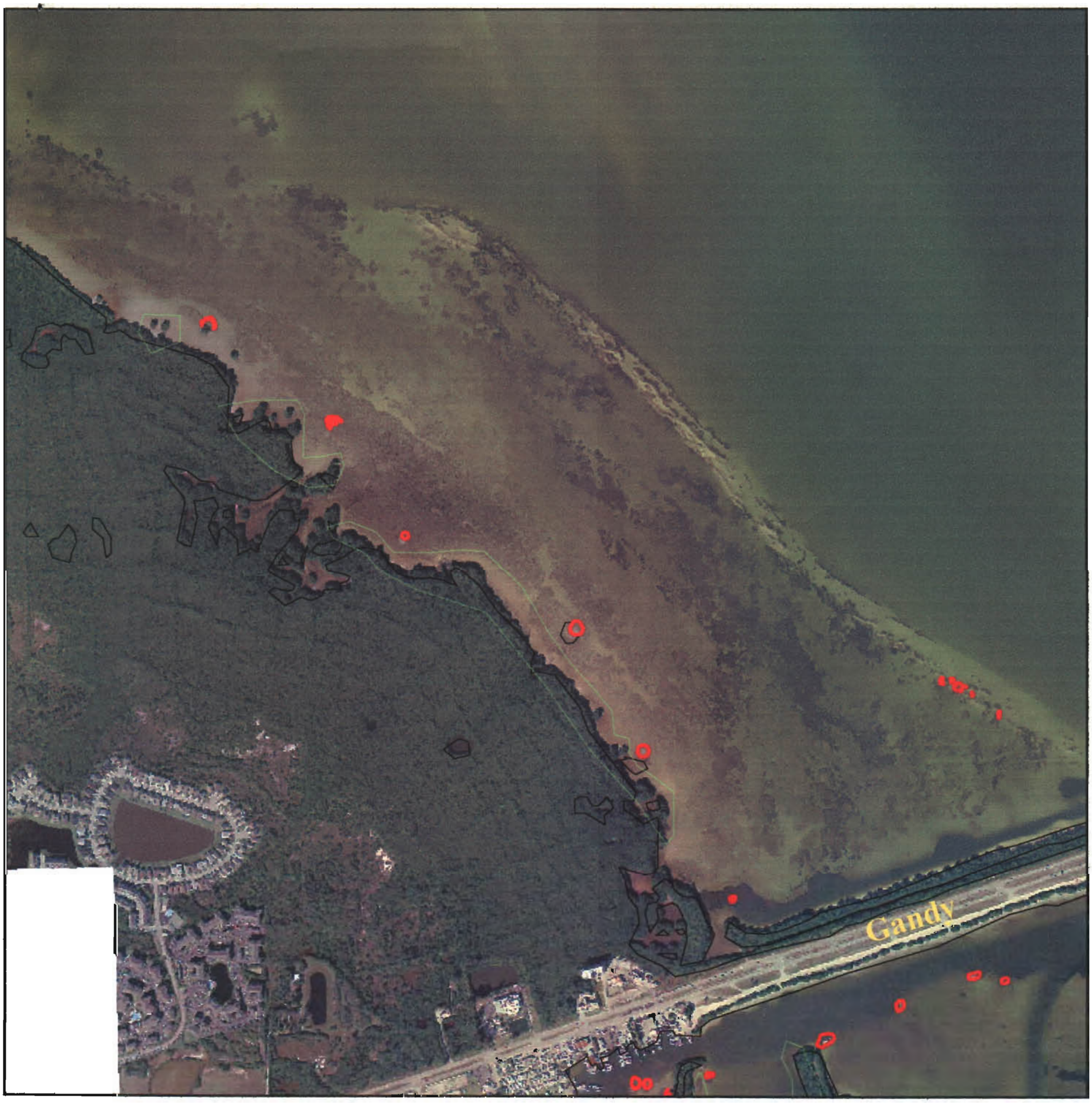
Meters
180 90 0 180

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites



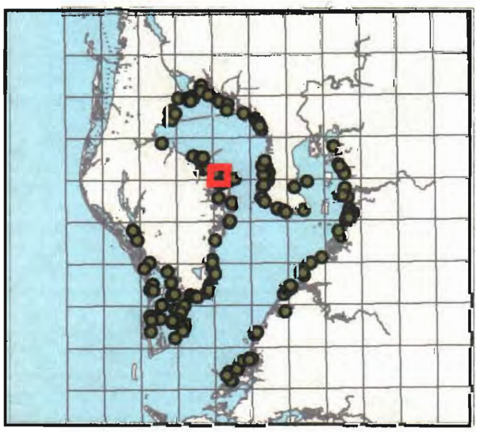
Oyster Mapping

North of Weedon Island
Snug Harbor

Meters
180 90 0 180

Fringing_reefs

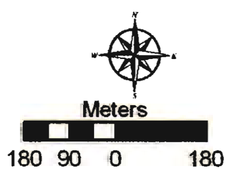
0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

North of Weedon Island
Snug Harbor



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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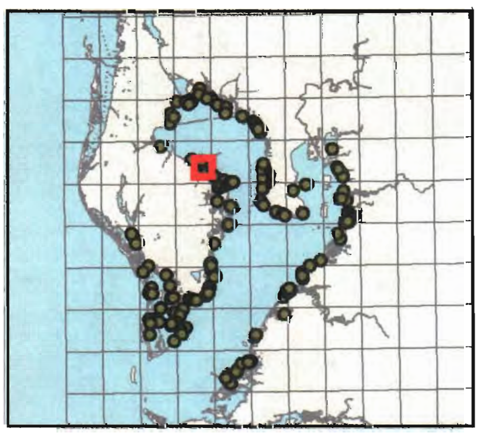
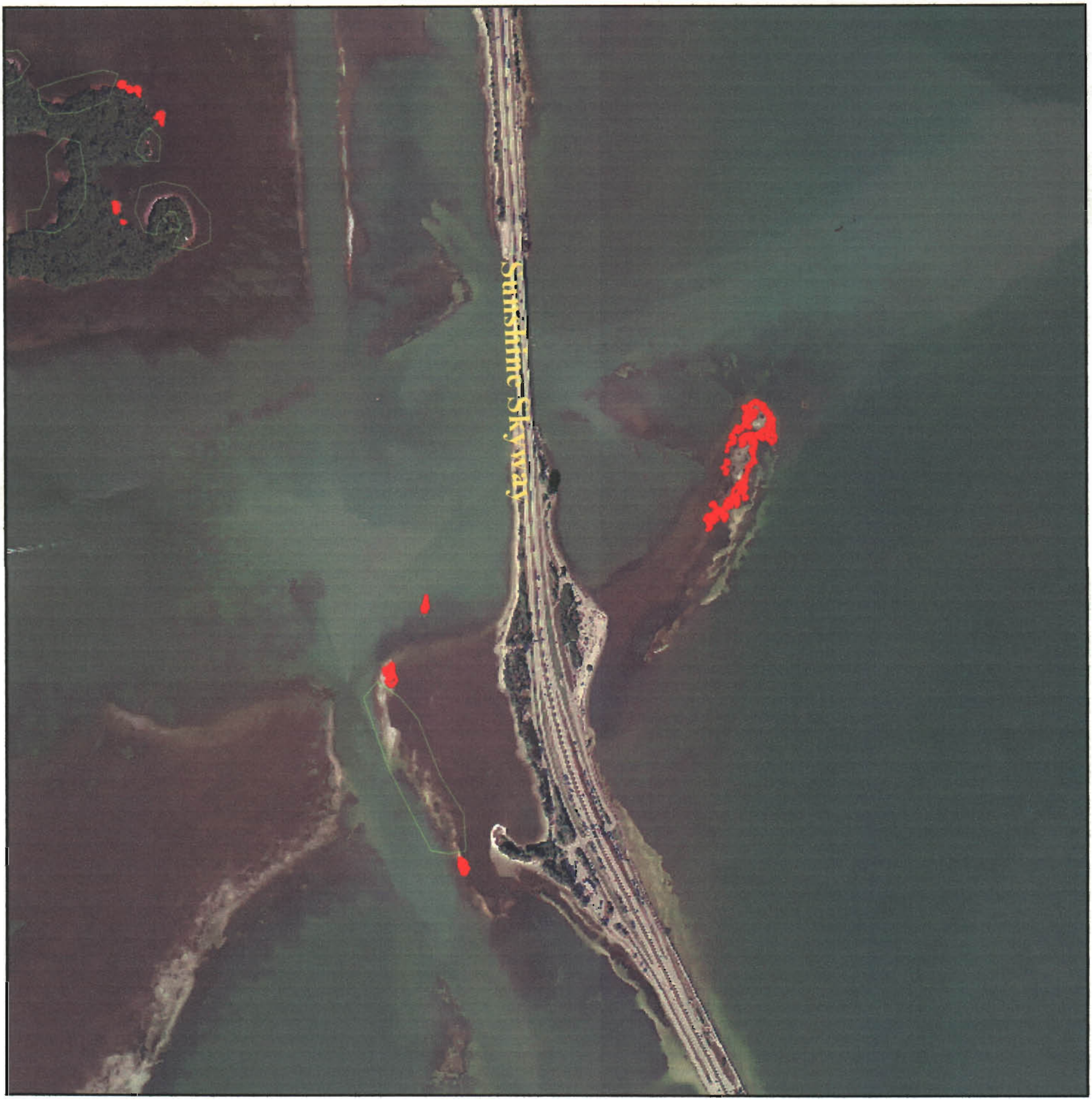
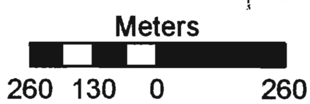


0630_NEPTUNE II_Oyster Bed_Sites



Oyster Mapping

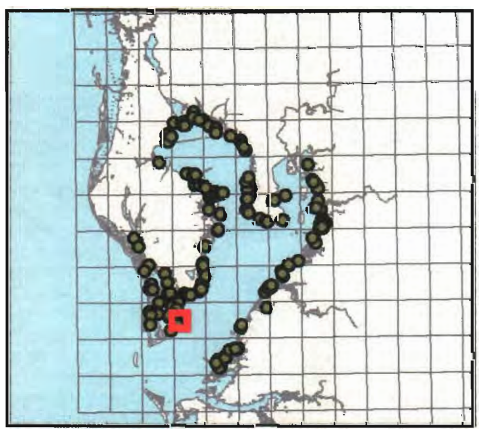


Tarpon Key

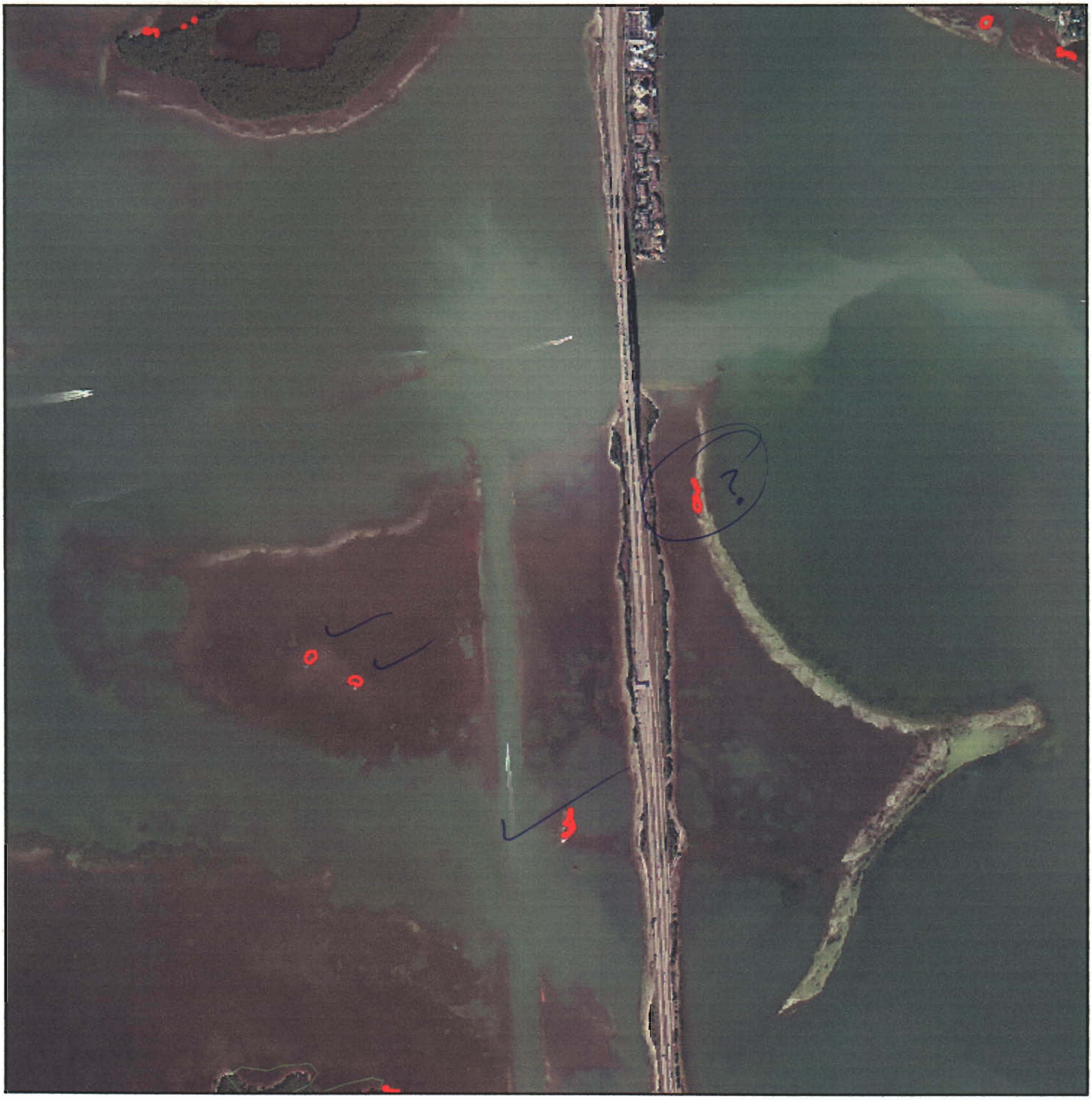
Oyster bed east of fishing pier??

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites



Oyster Mapping

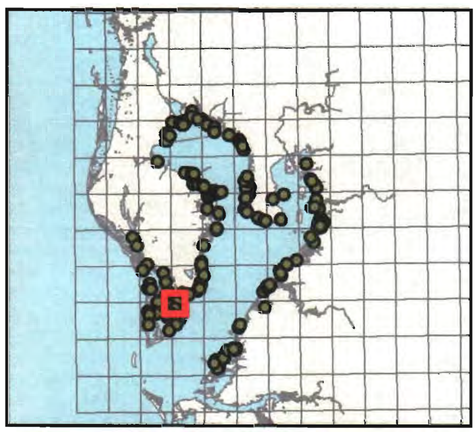
North of Tarpon Key on I-275, just south of Pinellas Point

Meters

350 175 0 350

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



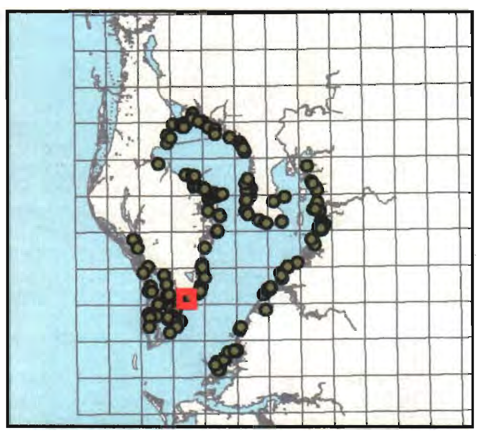
0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

240 120 0 240

Pinellas Point



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

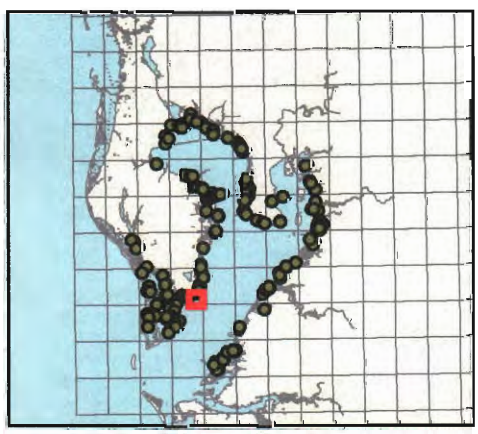
240 120 0 240

Pinellas Point

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

Return to Table of Contents



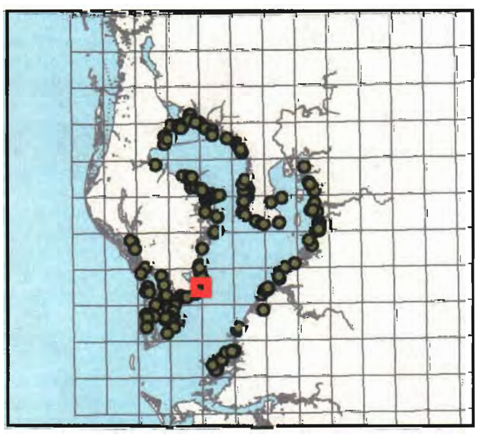
0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

220 110 0 220

Bahama Shores
Little Bayou



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

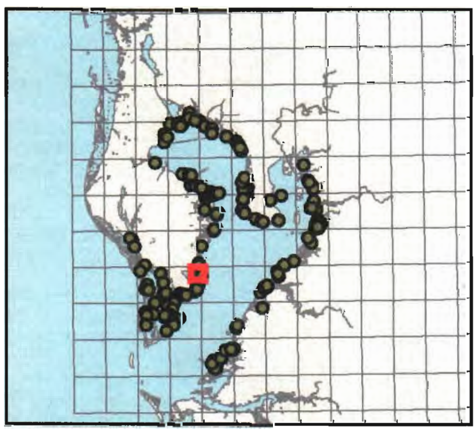
Meters

220 110 0 220

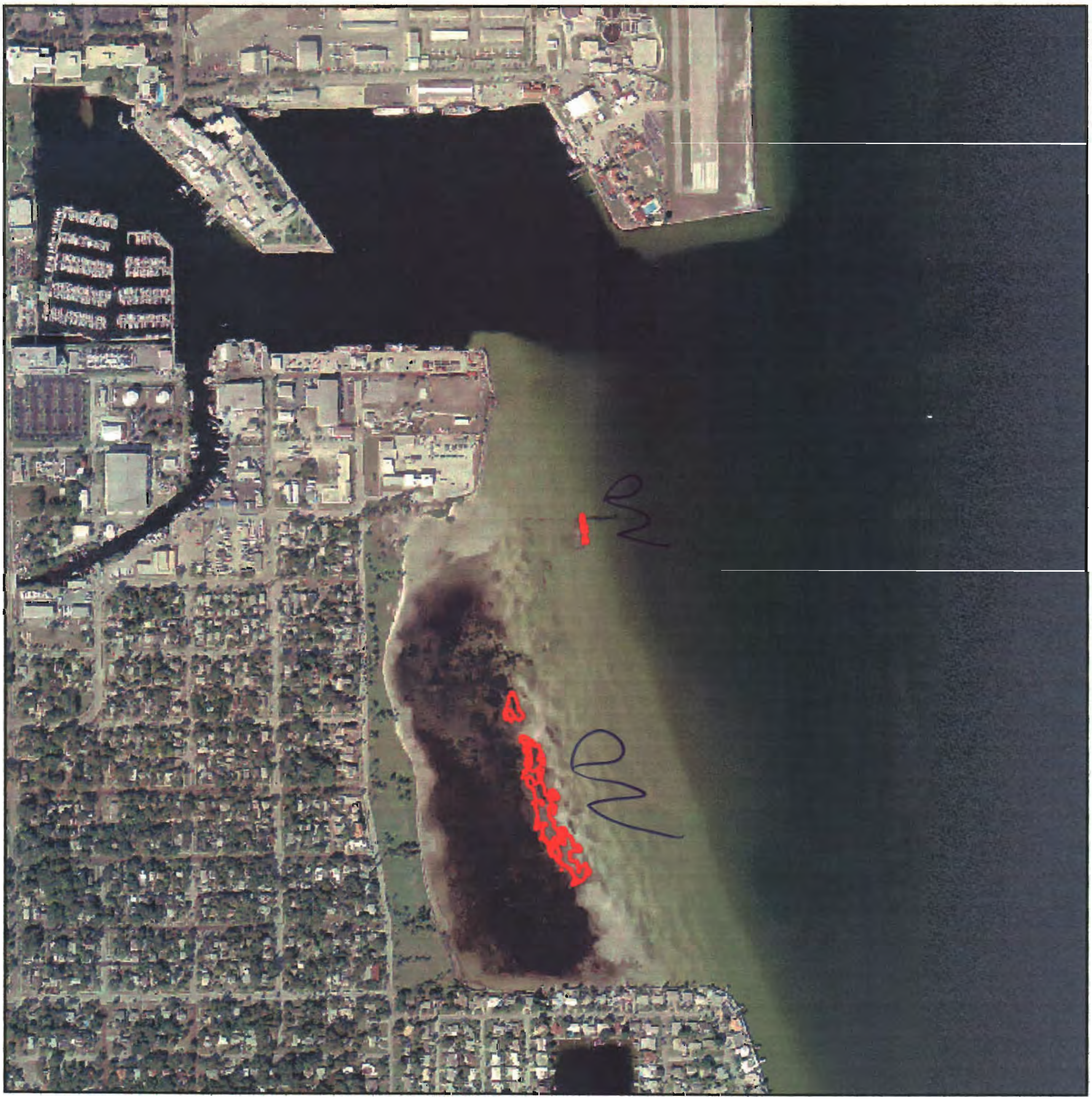
Coquina Key
Big Bayou

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites



Oyster Mapping

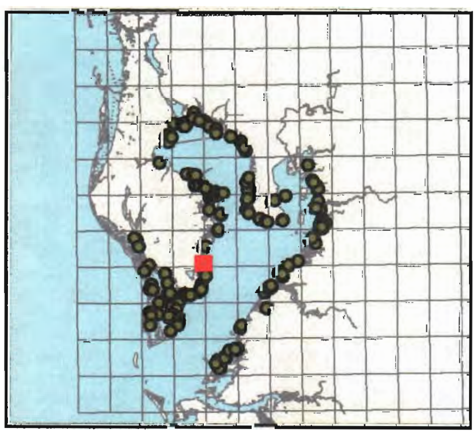
Meters

170 85 0 170

Tropical Shores
Bayboro Harbor

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

220 110 0 220

**Old Northeast
"The Pier" at bottom
of map.**

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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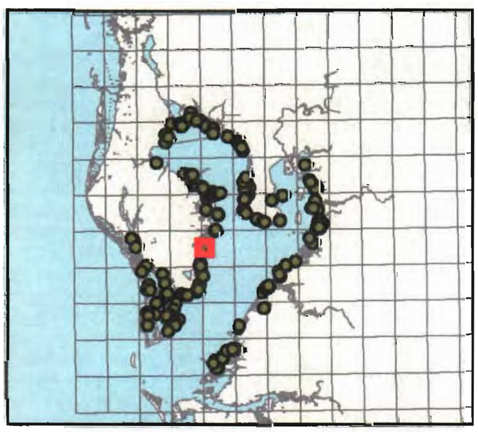


● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

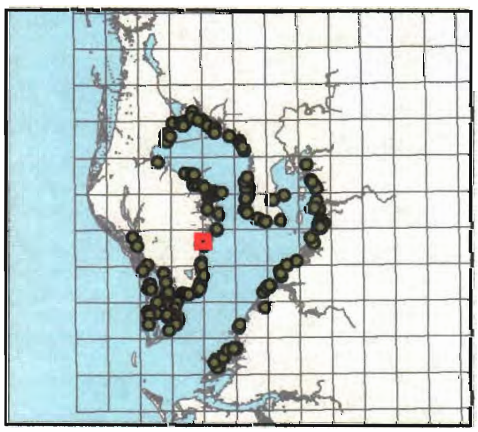
Meters

170 85 0 170

Coffee Port Bayou
Stouffer Vinoy Golf Club

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

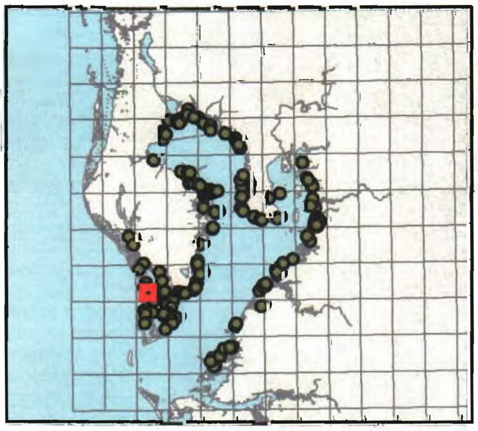
Meters

190 95 0 190

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites

3

Oyster Mapping

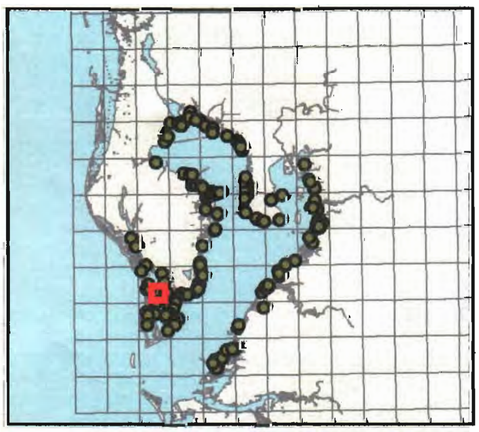
Meters

240 120 0 240

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

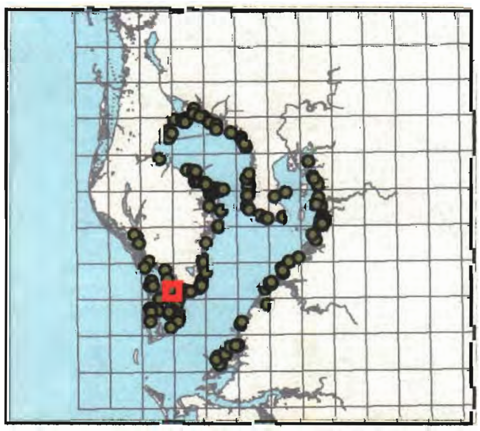
Meters

240 120 0 240

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites

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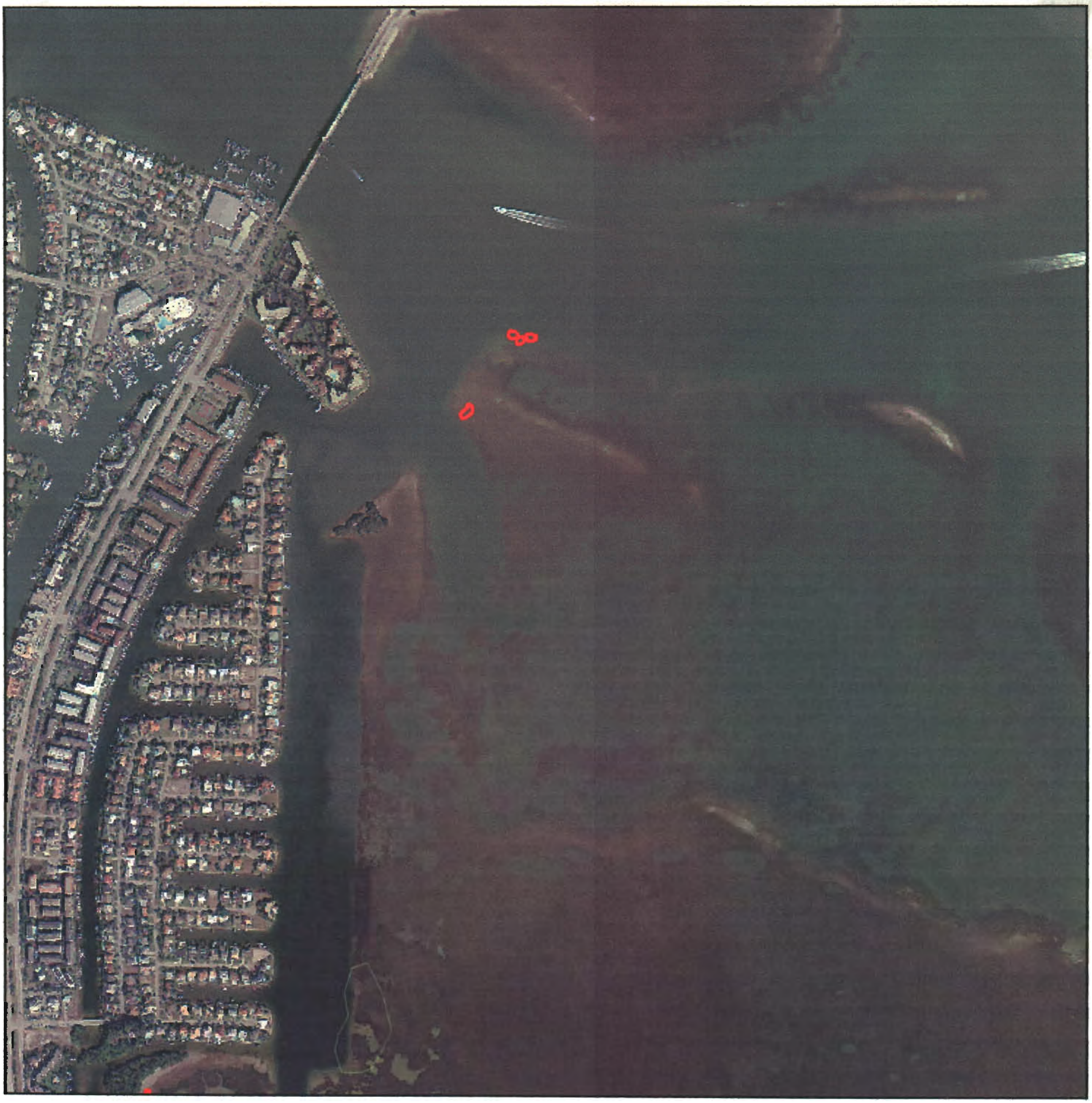
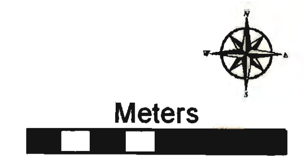
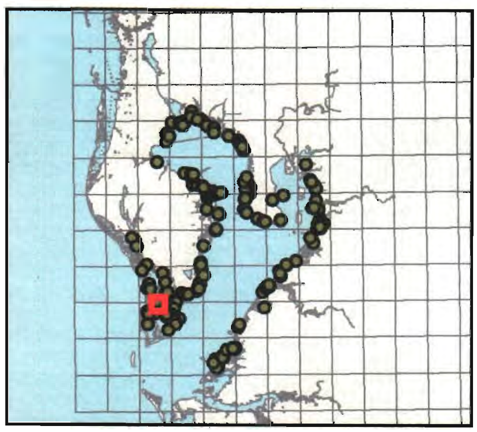


Oyster Mapping





Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

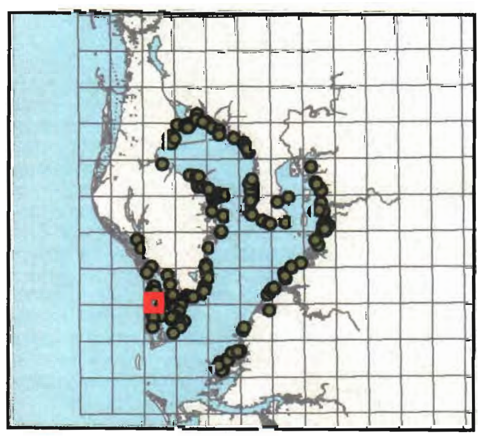
Meters

240 120 0 240

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

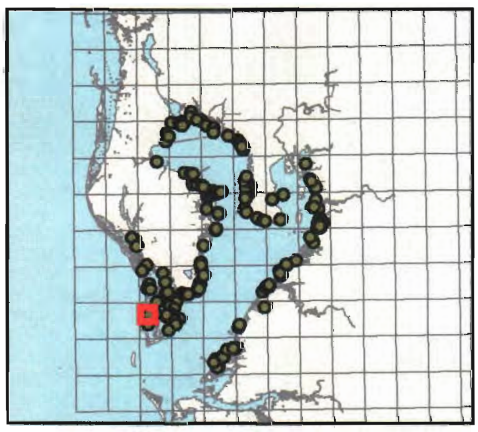
Meters

240 120 0 240

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

300 150 0 300

Mullet Key Bayou

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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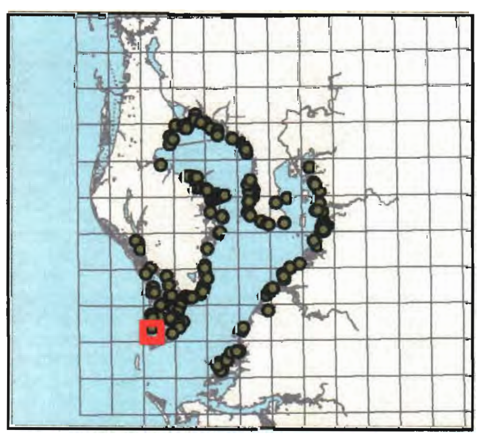


● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

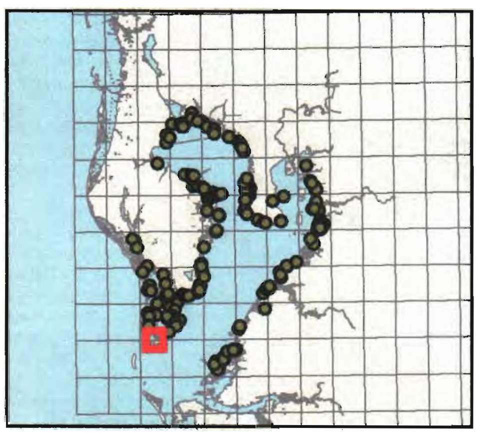
Meters

300 150 0 300

Mullet Key Bayou

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

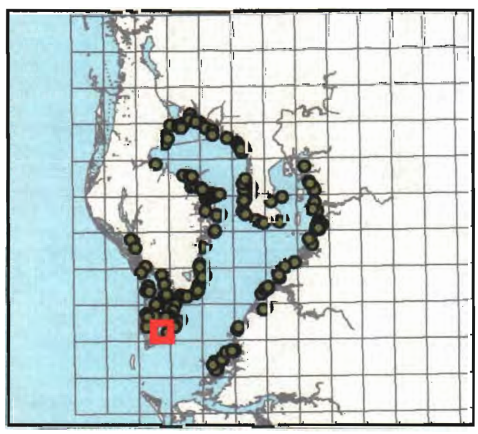
Meters

300 150 0 300

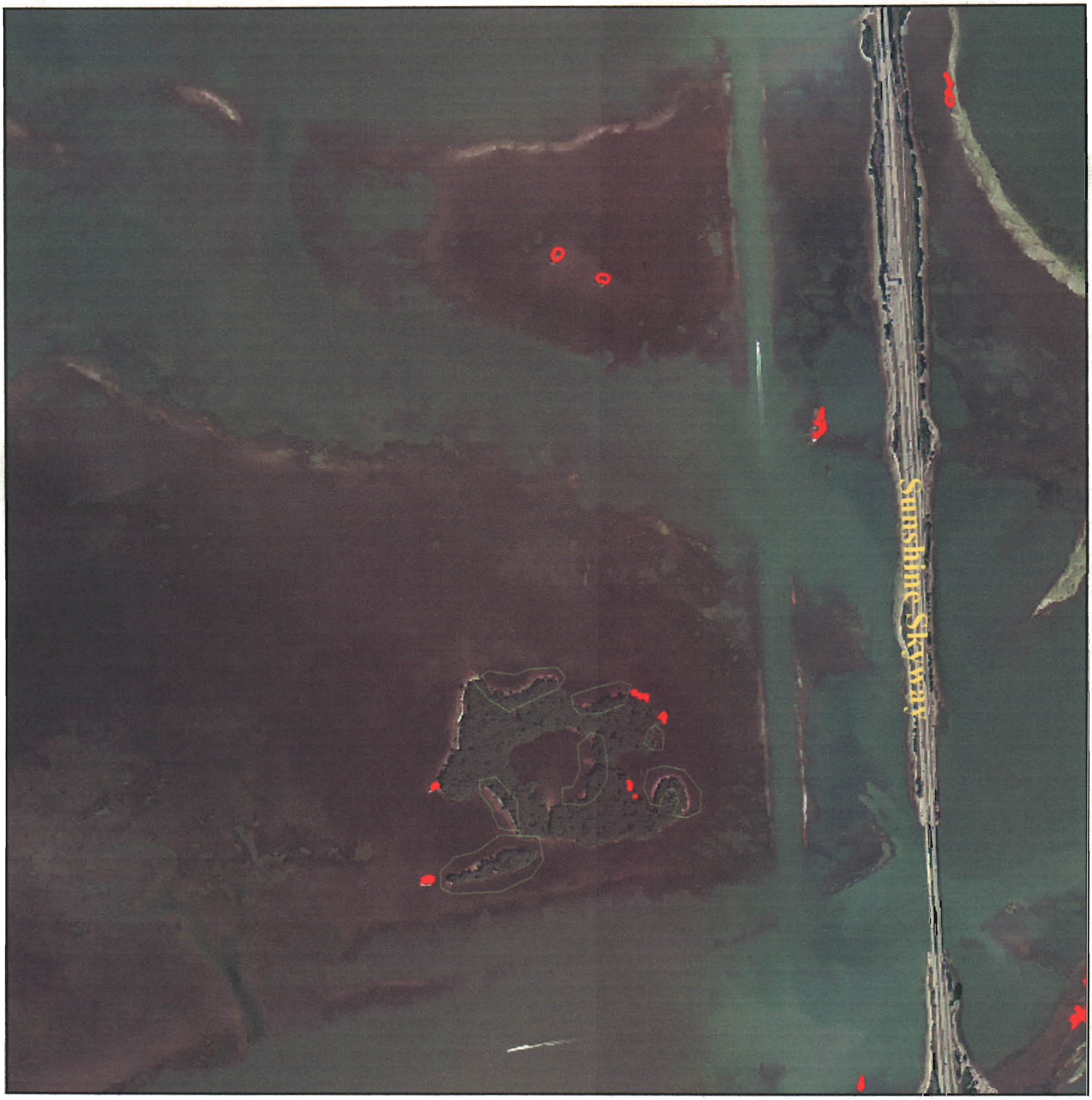
Mullet Key Bayou

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites



Oyster Mapping

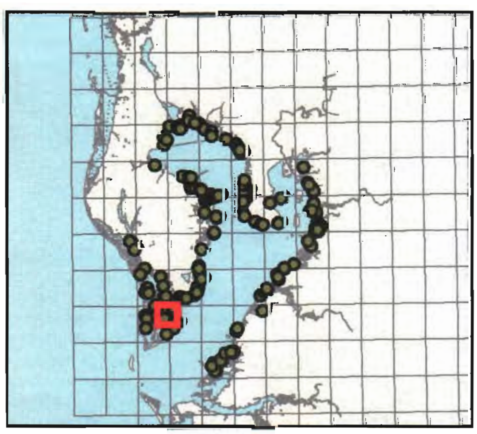
Meters

350 175 0 350

Tarpon Key

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

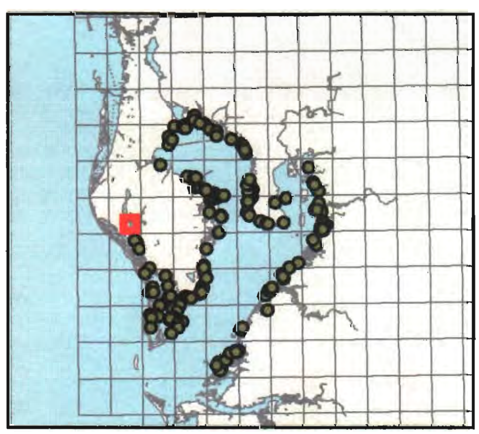


● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

200 100 0 200



Long Bayou

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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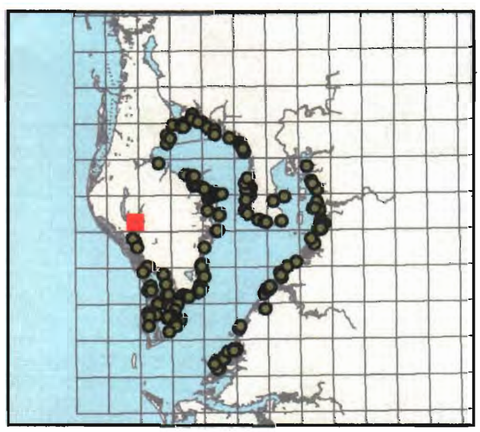
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

140 70 0 140

Cross Bayou



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

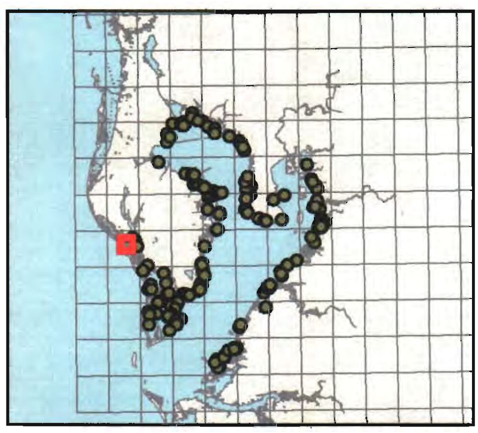
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

200 100 0 200

Boca Ciega, mid bay



Fringing_reefs

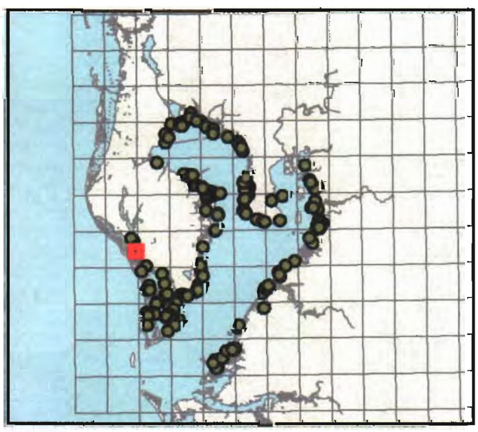
0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

150 75 0 150



Boca Ciega, mid bay

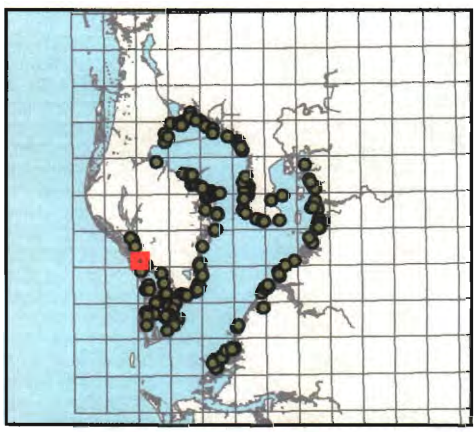
Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters
175 87.5 0 175



Boca Ciega, Proper

Fringing_reefs
0630_NEPTUNE II_Oyster Bed_Polygons
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● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

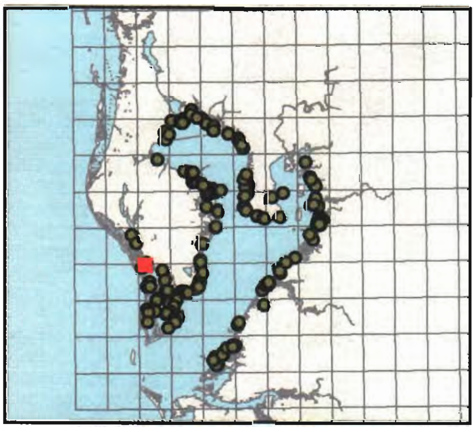
Meters

120 60 0 120

Boca Ciega, Proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

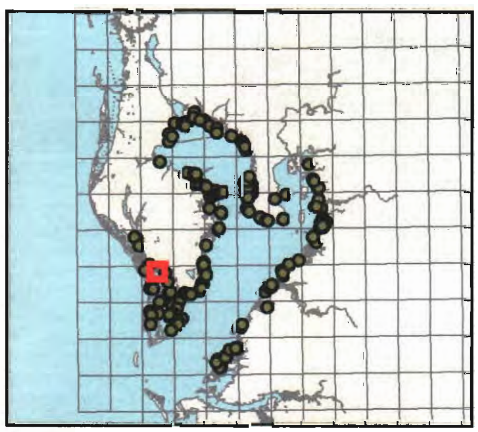
Meters

250 125 0 250

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

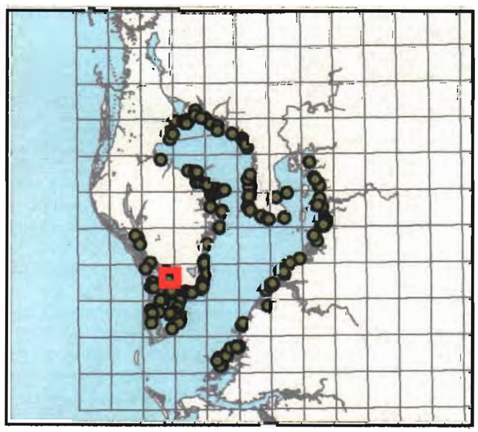
Meters

250 125 0 250

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

250 125 0 250

Boac Ciega Bay, proper

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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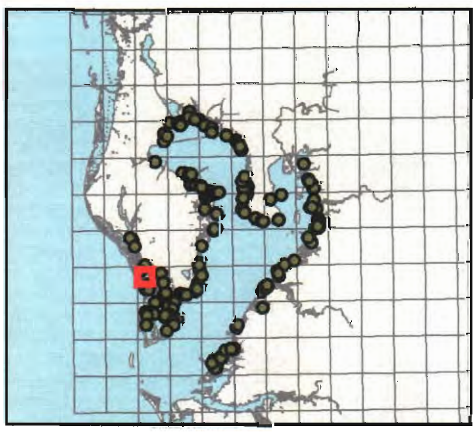
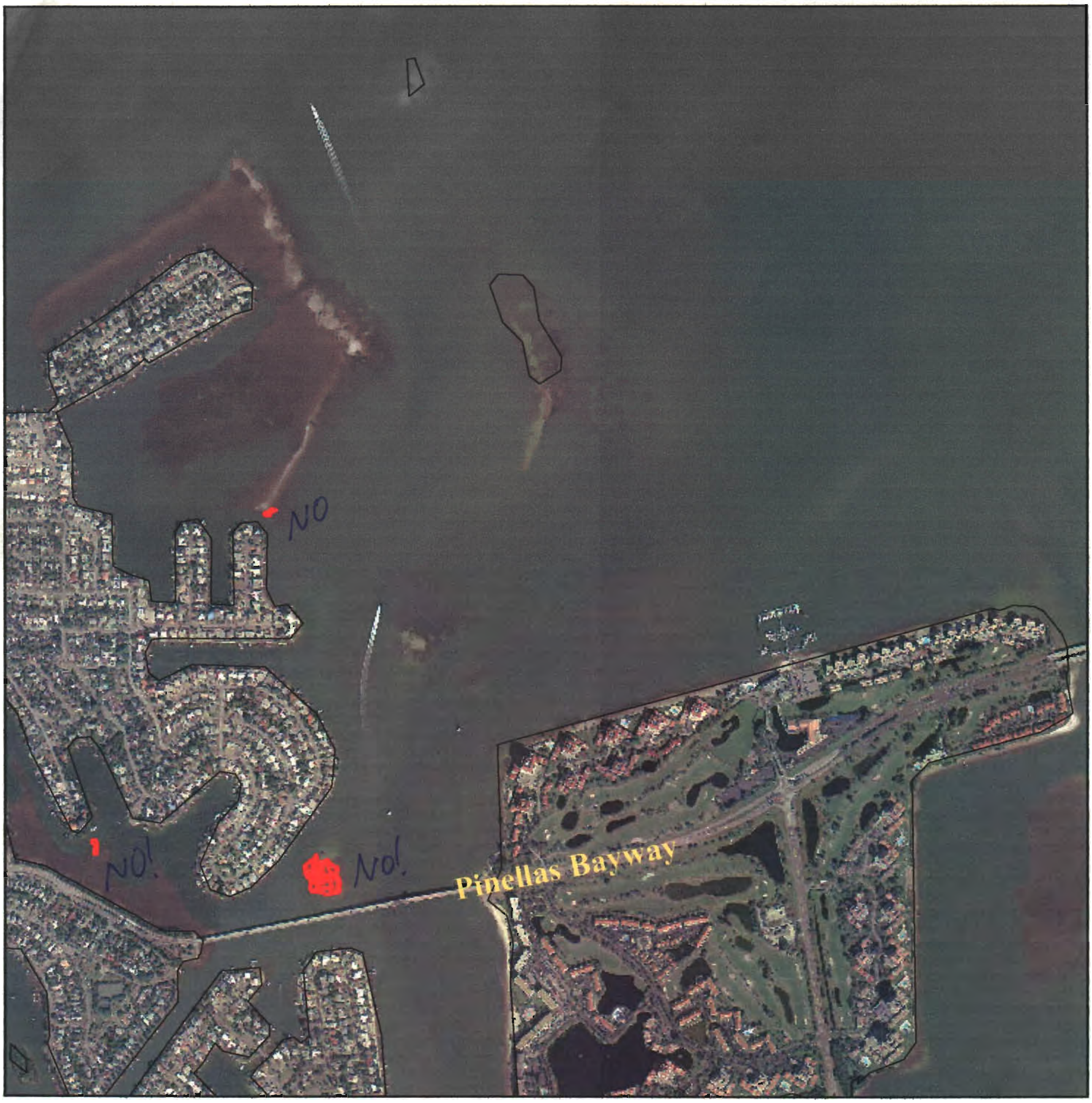


0630_NEPTUNE II_Oyster Bed_Sites

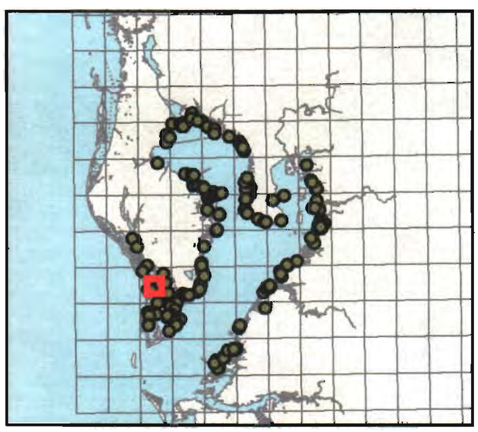


Oyster Mapping

Meters

250 125 0 250

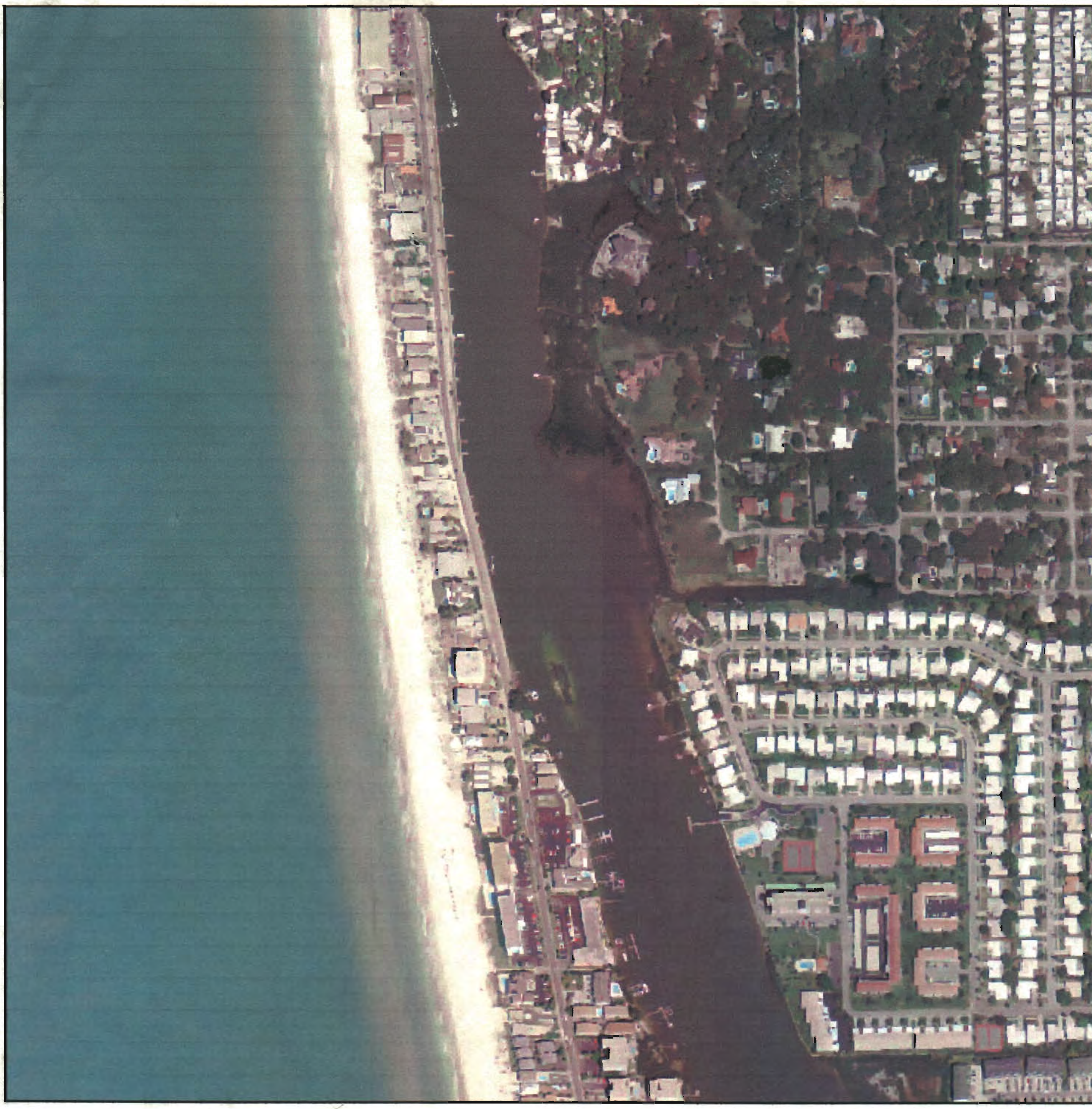
Boac Ciega Bay, proper



Fringing_reefs

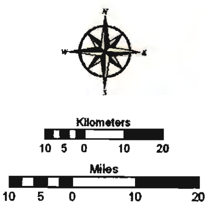
0630_NEPTUNE II_Oyster Bed_Polygons

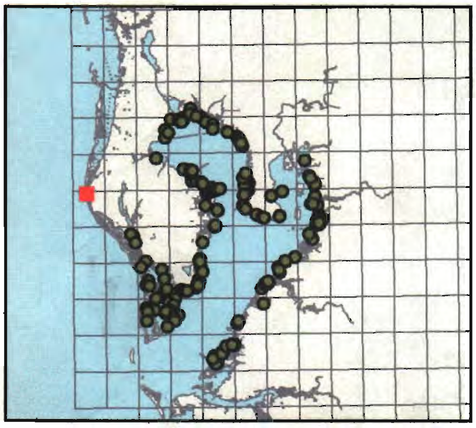
0630_NEPTUNE II_Oyster Bed_Sites



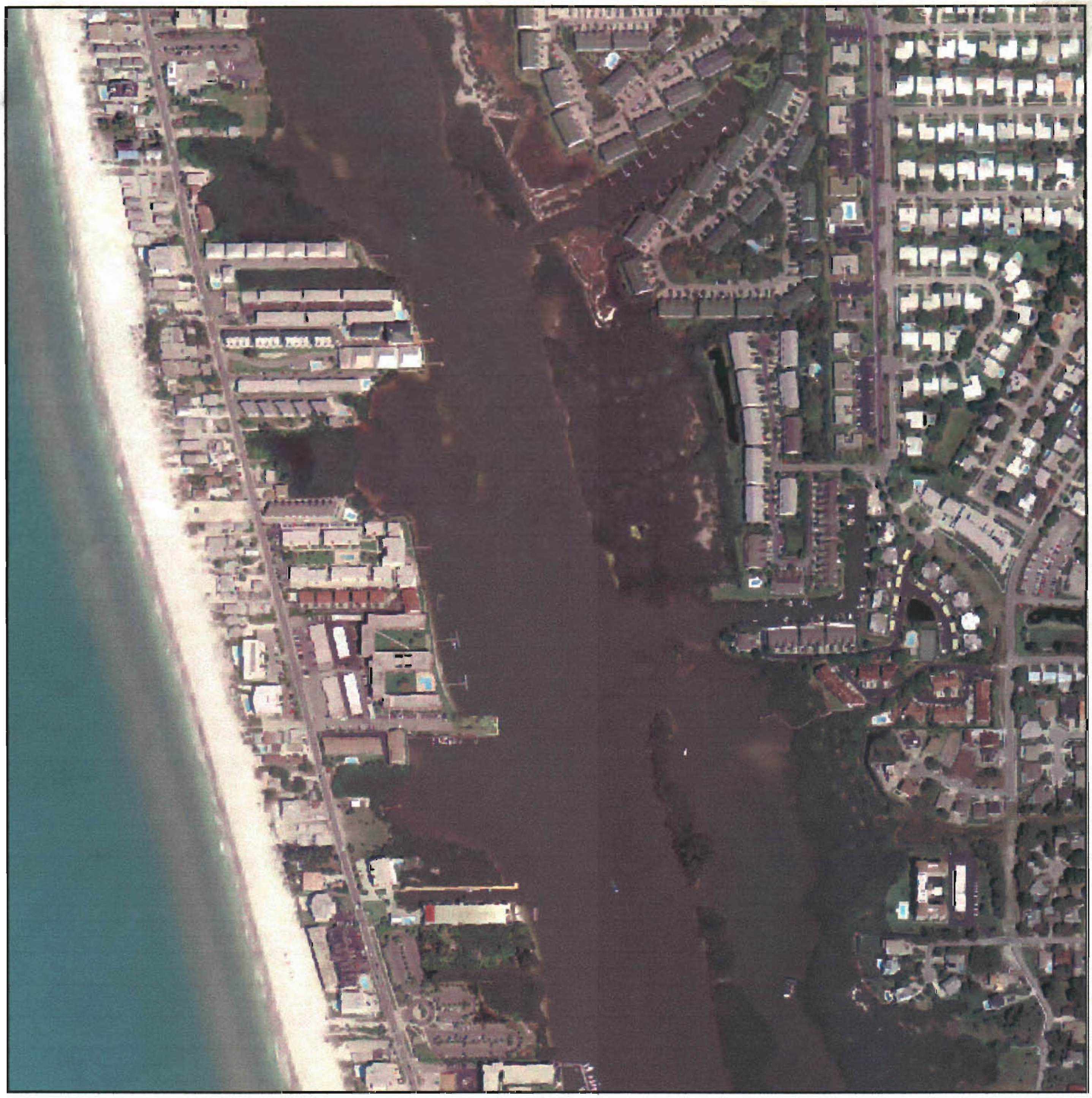
Oyster Mapping

Boca Ciega Bay, the Narrows

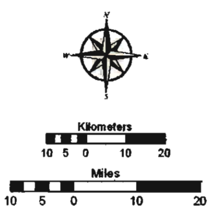


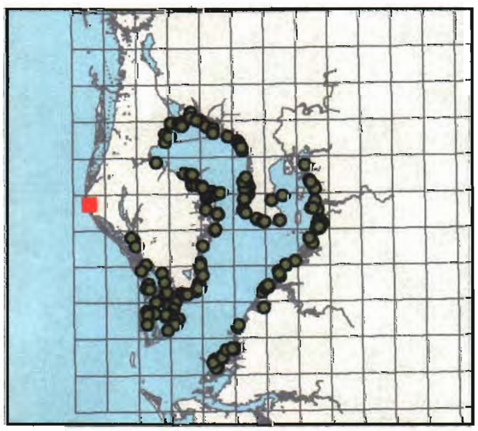


● 0630_NEPTUNE II_Oyster Bed_Sites



Oyster Mapping





Boca Ciega Bay, northern area

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

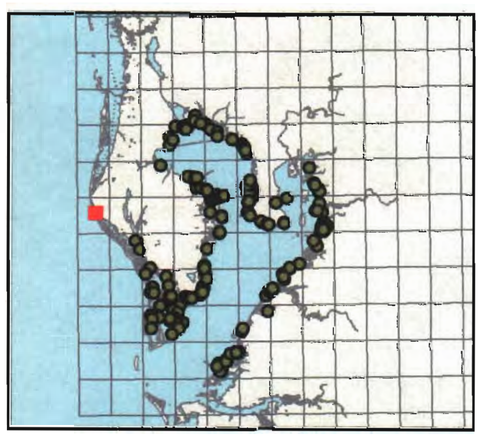
Meters

100 50 0 100

Boca Ciega Bay, northern area

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



0630_NEPTUNE II_Oyster Bed_Sites

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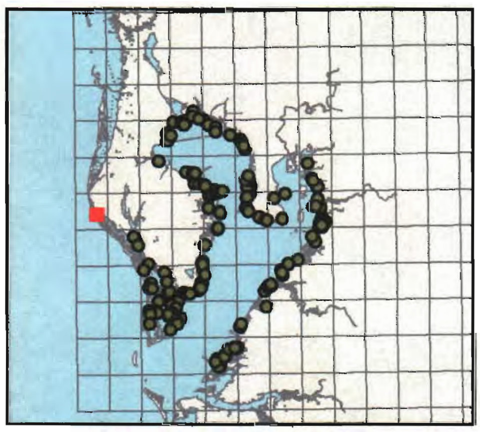
Oyster Mapping

Meters

100 50 0 100

Boca Ciega Bay, northern area



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

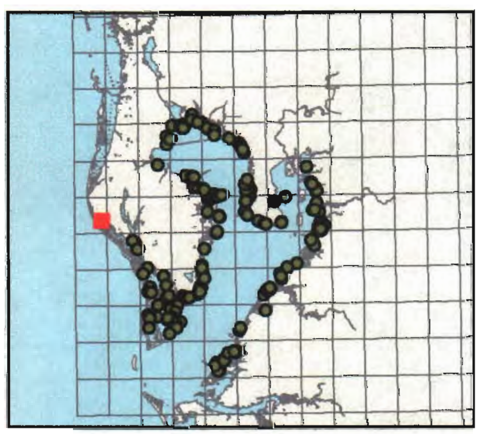
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

130 65 0 130

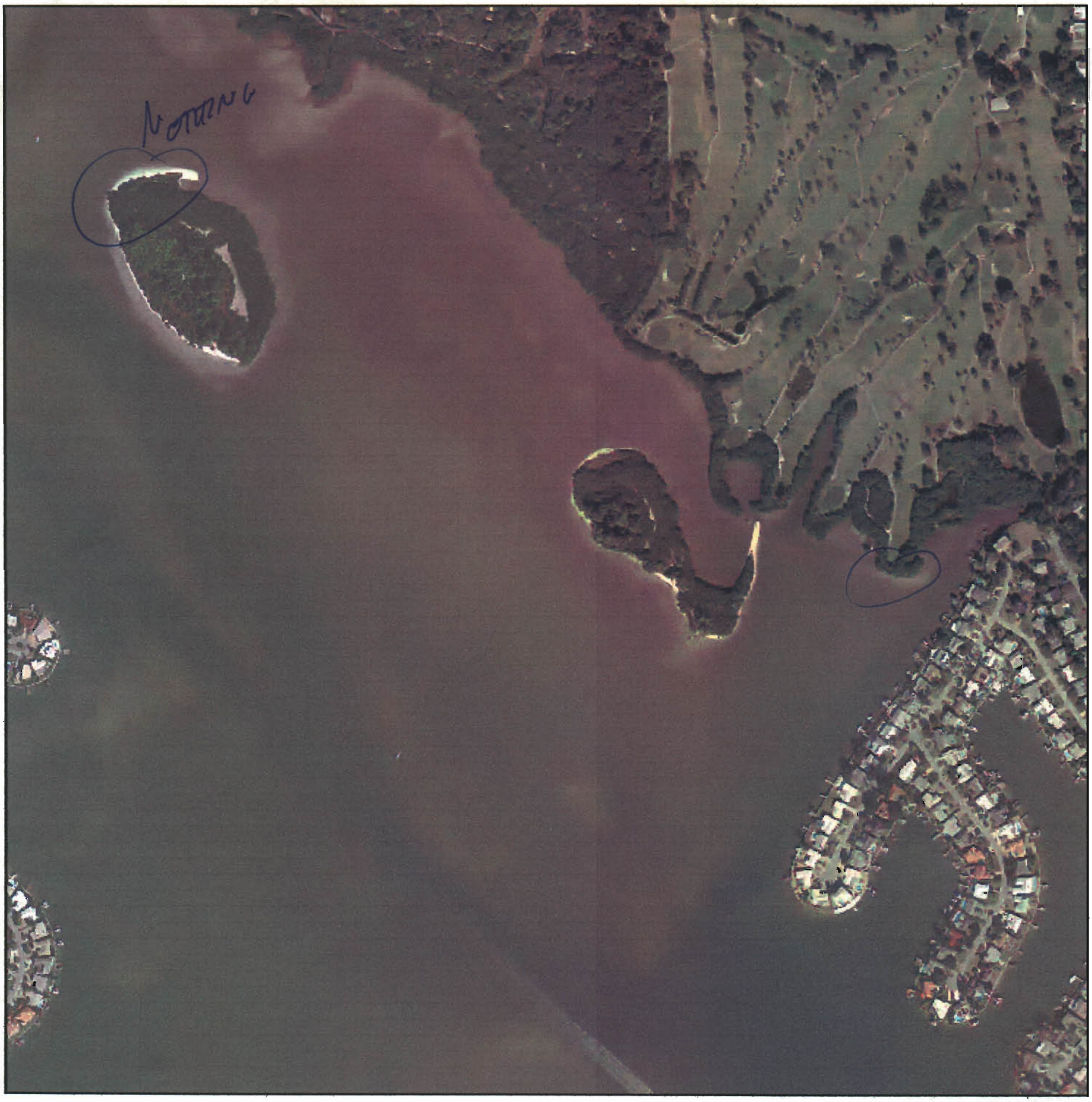
Boca Ciega Bay, northern area



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

0630_NEPTUNE II_Oyster Bed_Sites

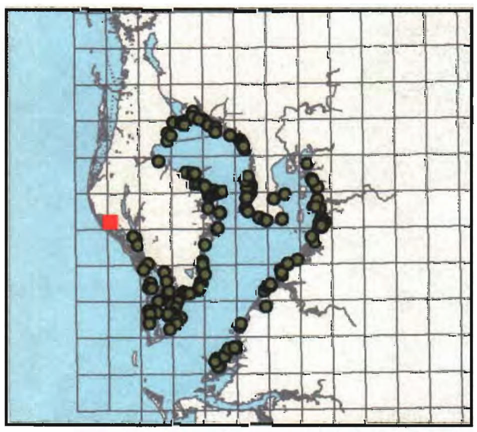


Oyster Mapping

Meters

110 55 0 110

Boca Ciega Bay, northern area



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

175 87.5 0 175

Boca Ciega Bay, northern area

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

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● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

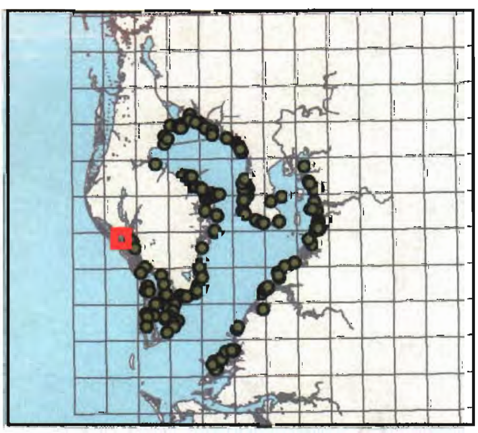
Meters

220 110 0 220

Boca Ciega Bay, northern area

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

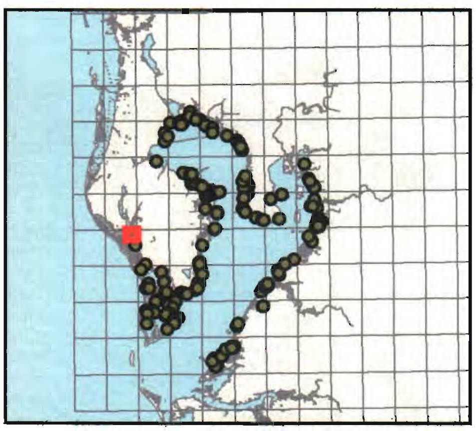


● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters
160 80 0 160

Long Bayou, mouth



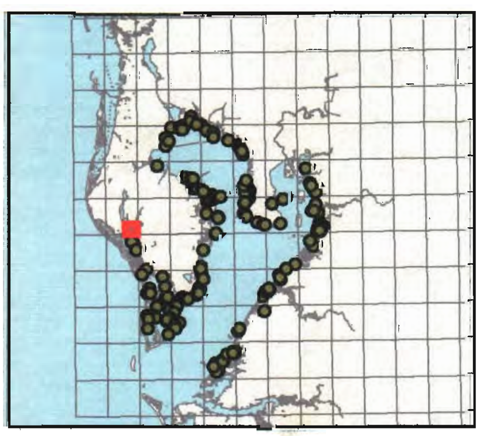
Fringing_reefs
0630_NEPTUNE II_Oyster Bed_Polygons
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Meters

160 80 0 160

Long Bayou, mouth



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

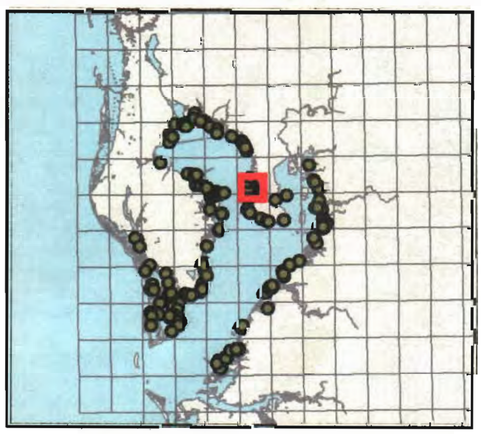
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Mac Dill

Meters

380 190 0 380



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

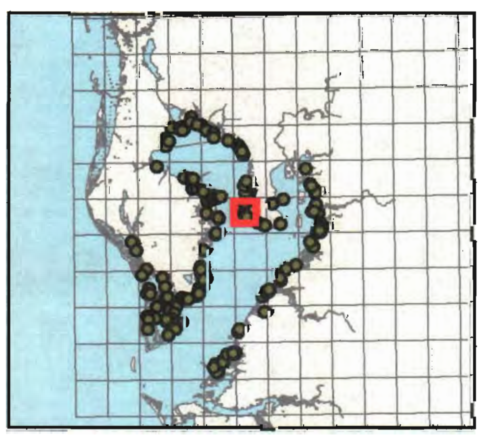
Return to Table of Contents

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Mac Dill

Meters
380 190 0 380



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

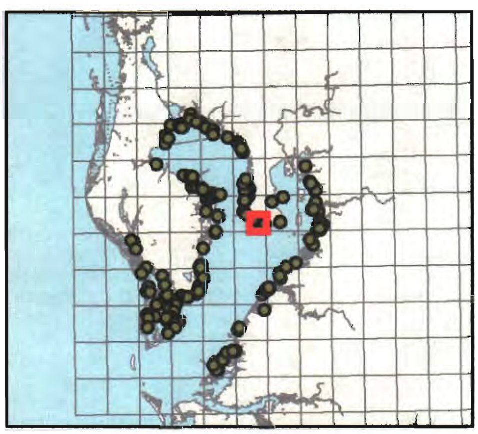
0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Mac Dill

Meters

290 145 0 290



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

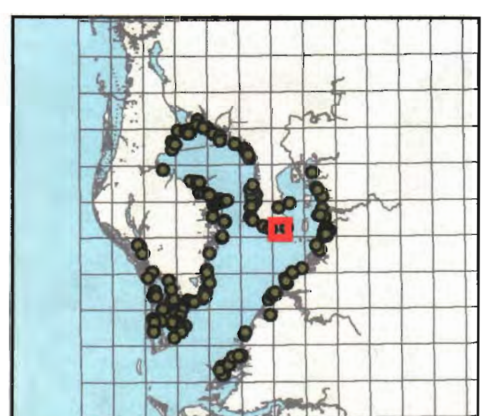
Meters

290 145 0 290

Mac Dill

Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons



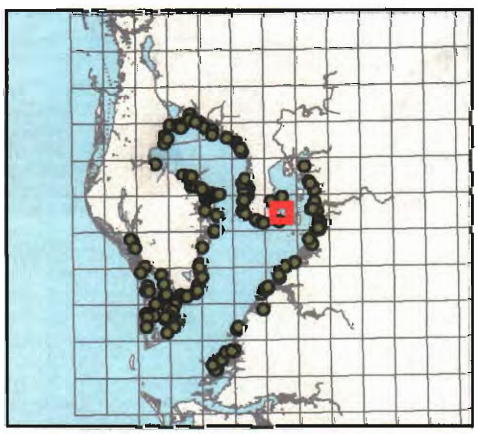
● 0630_NEPTUNE II_Oyster Bed_Sites

Oyster Mapping

Mac Dill

Meters

290 145 0 290



Fringing_reefs

0630_NEPTUNE II_Oyster Bed_Polygons

● 0630_NEPTUNE II_Oyster Bed_Sites

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Oyster Mapping

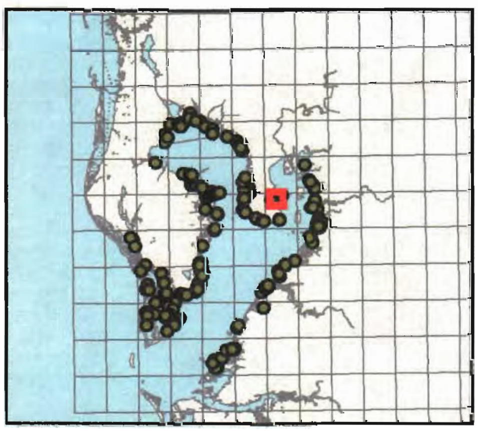
Mac Dill
Hillsborough Bay

Meters

180 90 0 180

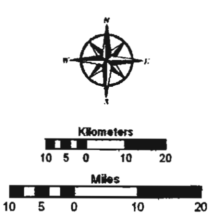
Fringing_reefs

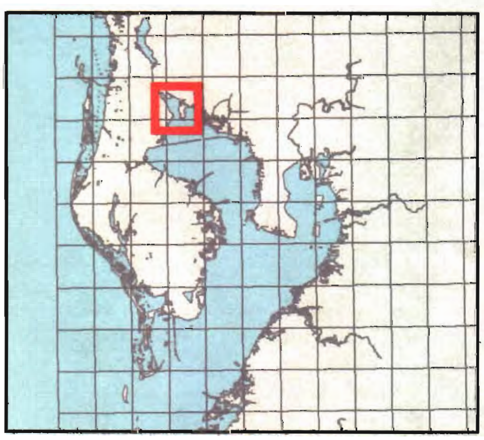
0630_NEPTUNE II_Oyster Bed_Polygons



● 0630_NEPTUNE II_Oyster Bed_Sites

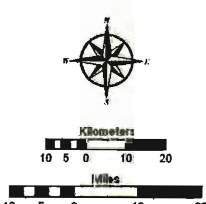
Oyster Mapping

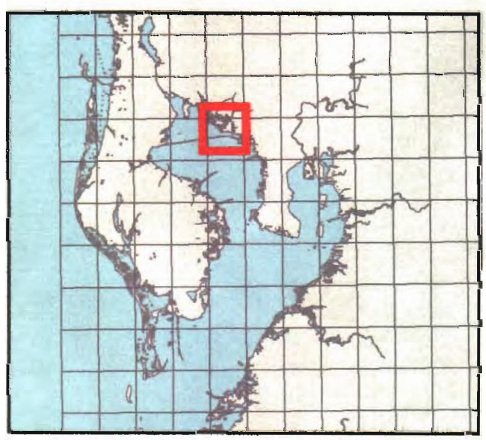




Map 11

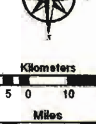
Oyster Mapping





Map 12

Oyster Mapping

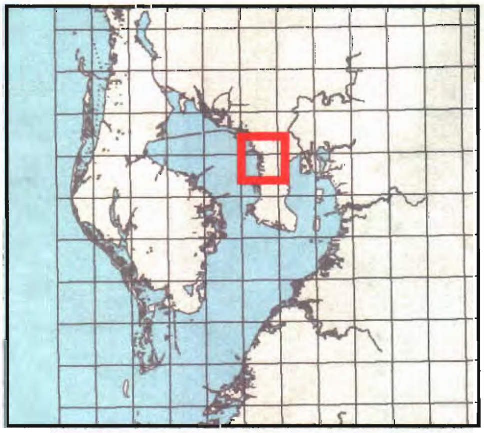


Kilometers

10 5 0 10 20

Miles

10 5 0 10 20



Map 13

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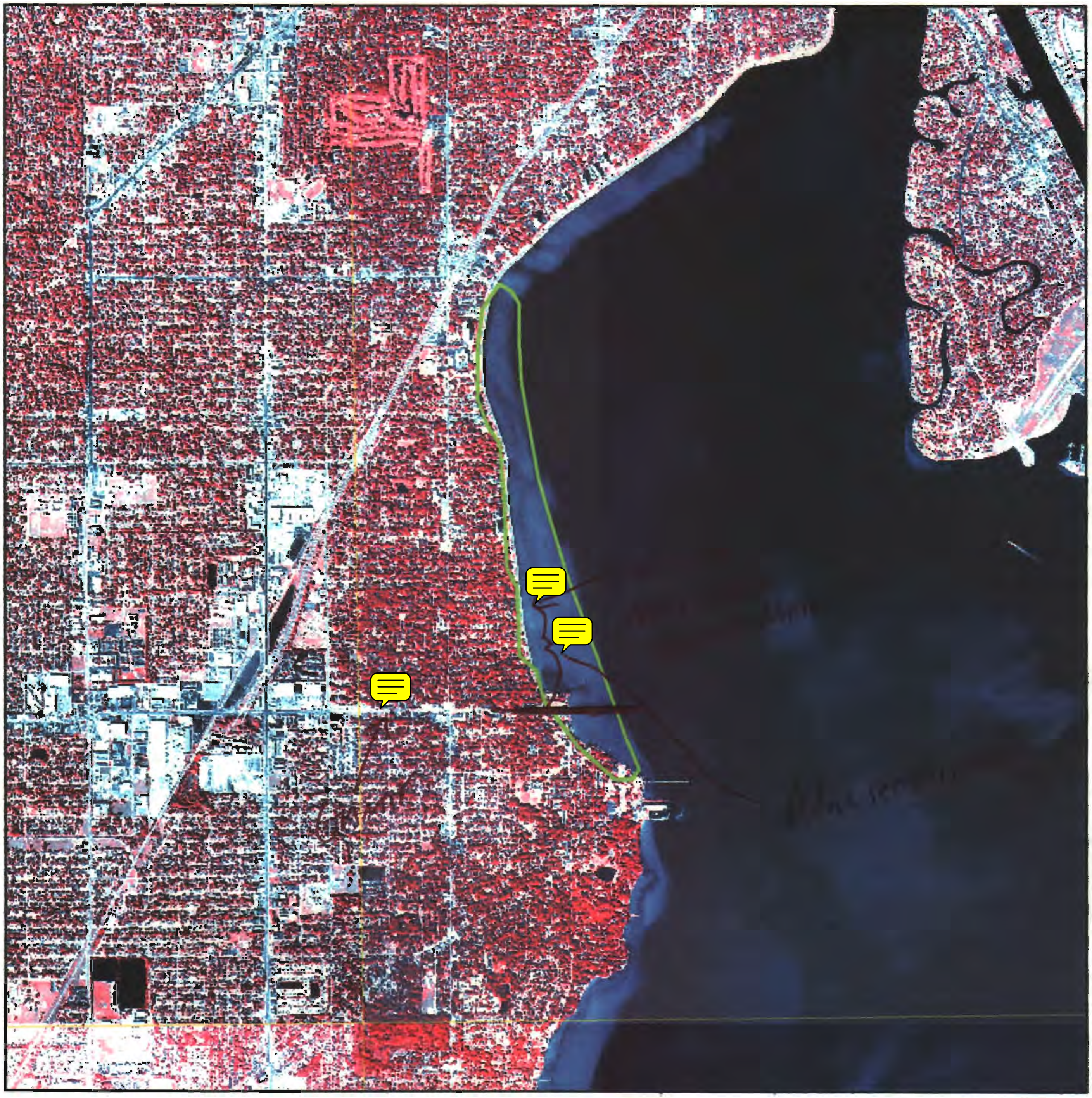
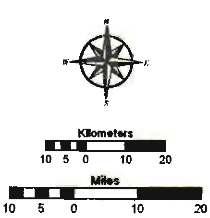
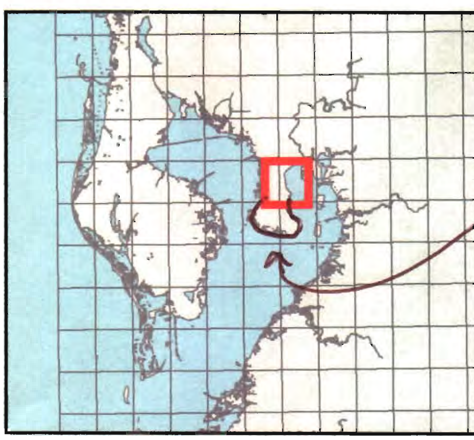


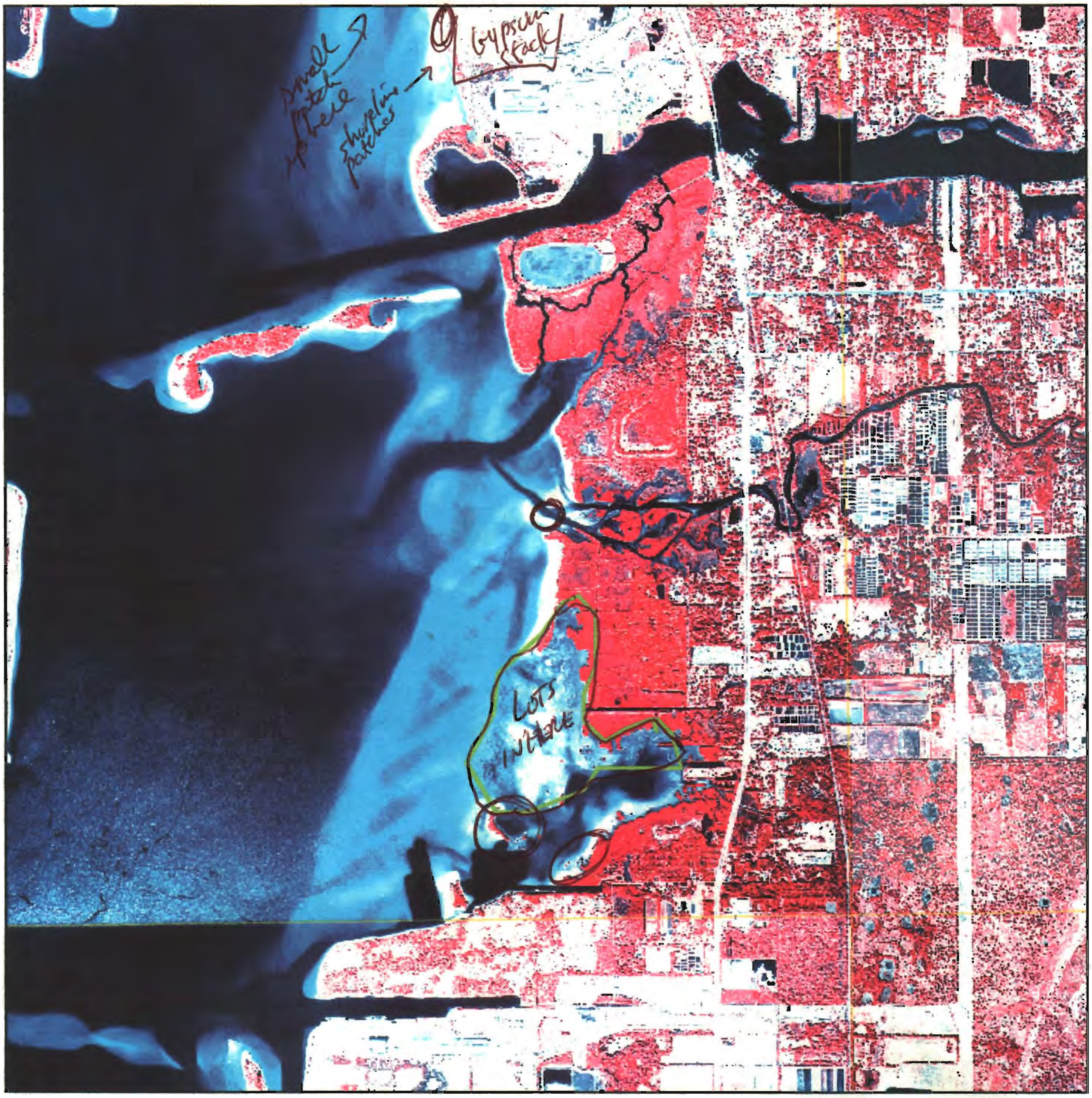
Oyster Mapping



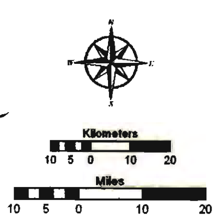


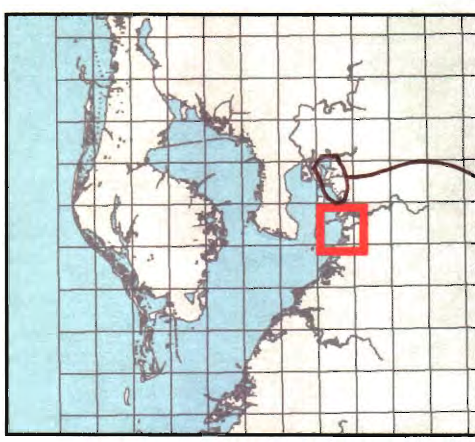
STILL NEED TO DO INTERBAY SOUTH OF GANDY.

Map 14



Oyster Mapping





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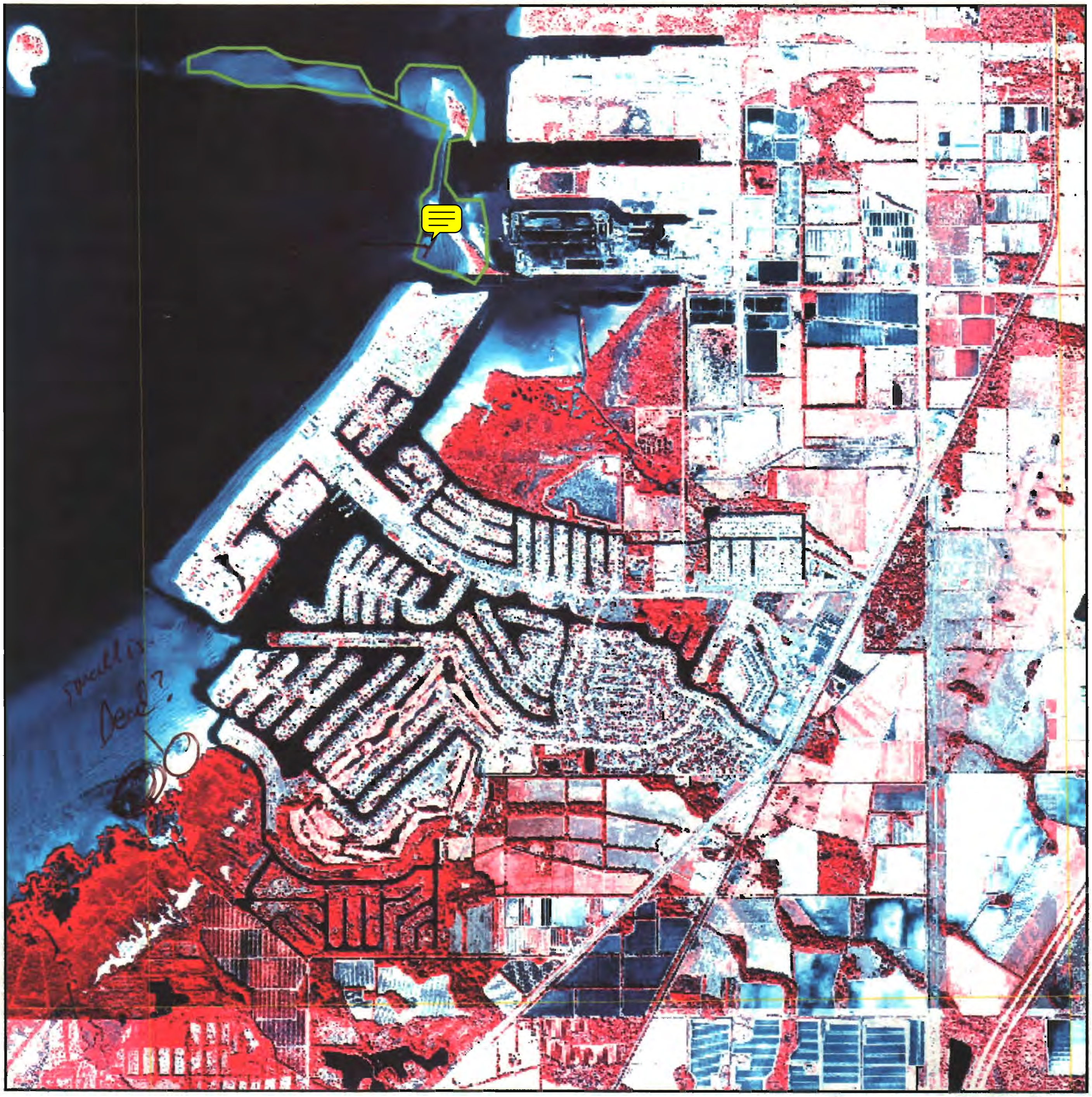
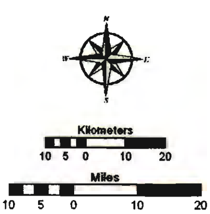
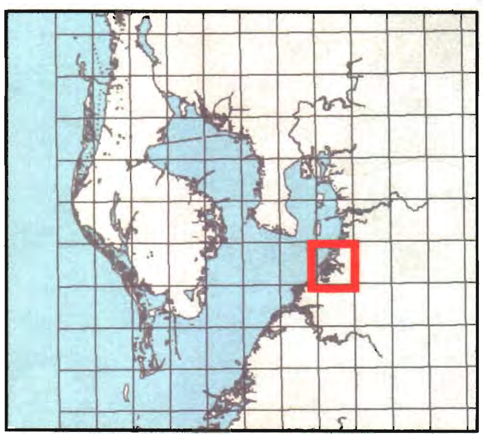


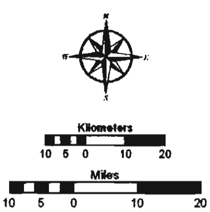
Oyster Mapping

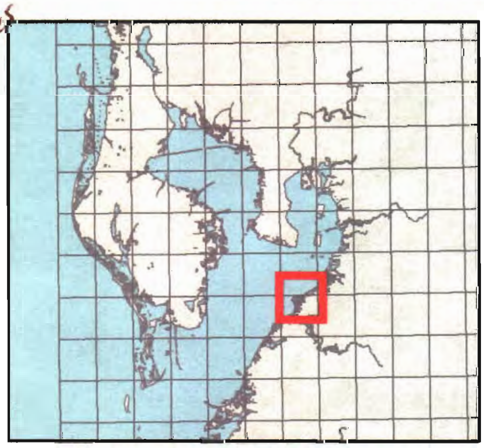




Map 16

Oyster Mapping





Map 17

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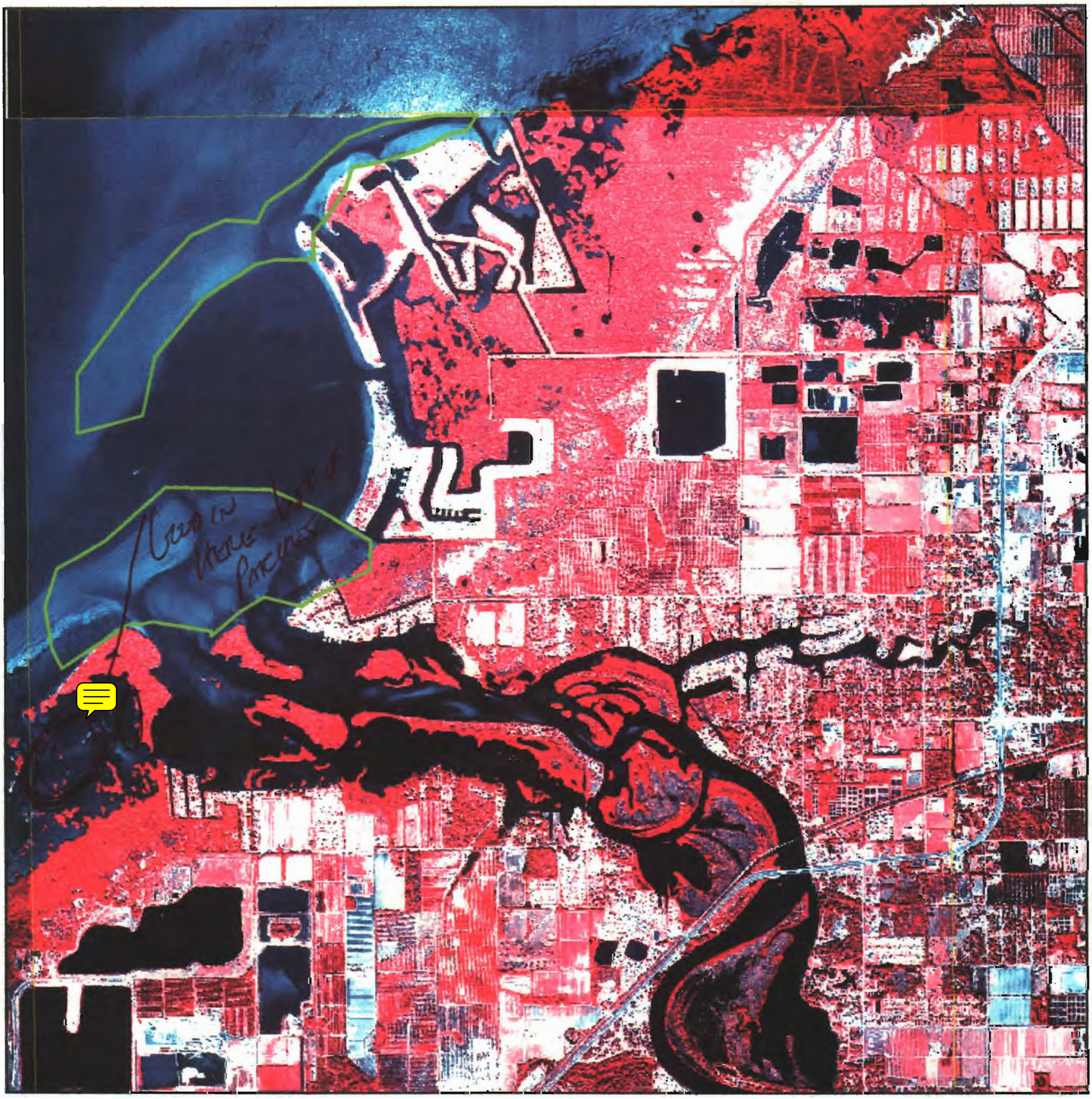
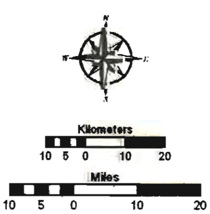
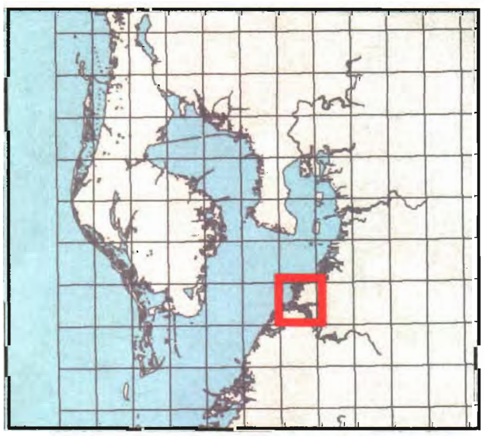


Oyster Mapping





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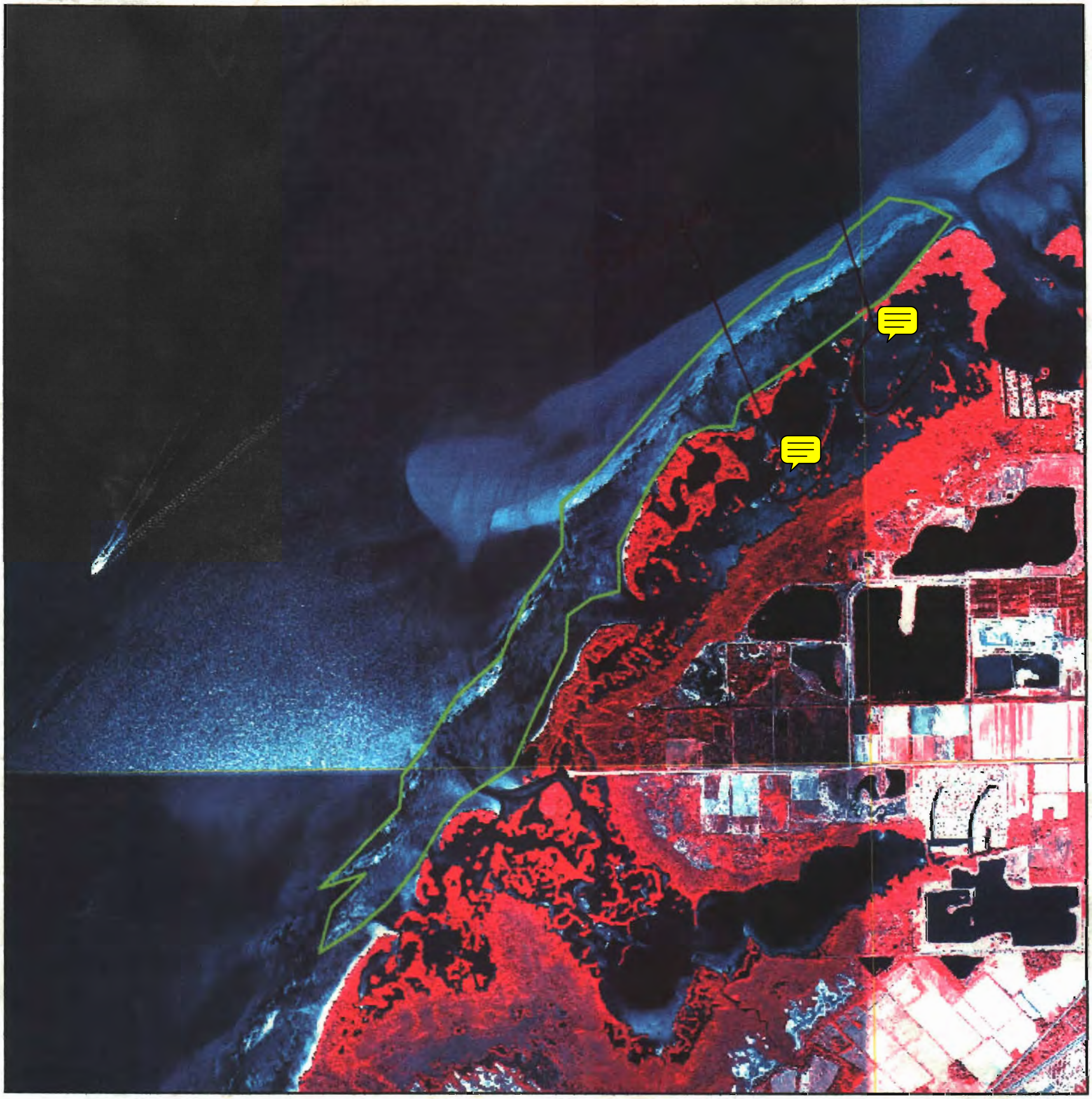
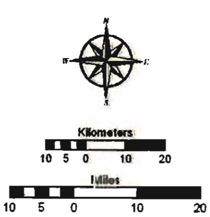
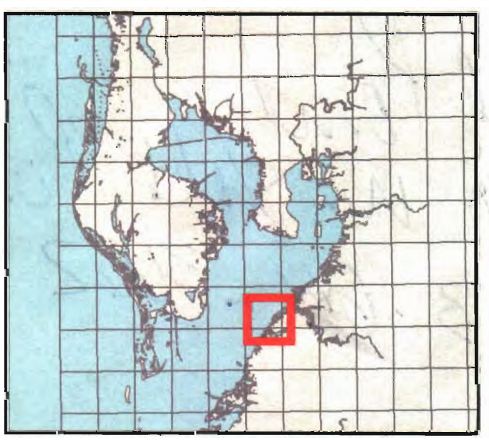


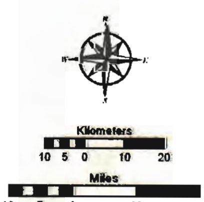
Oyster Mapping

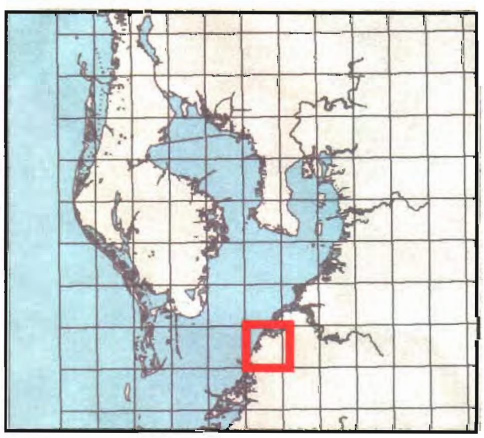




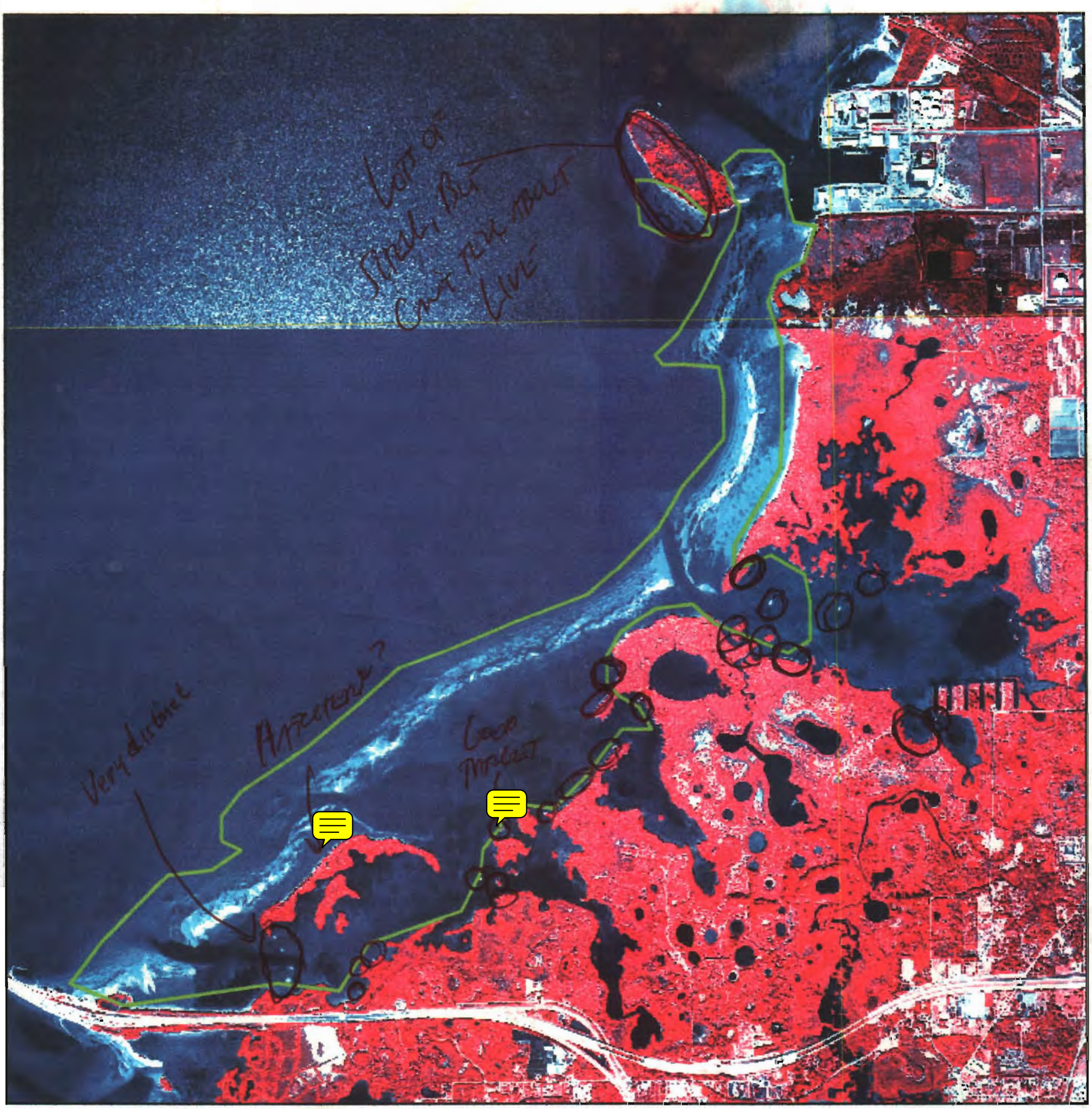
Map 19

Oyster Mapping

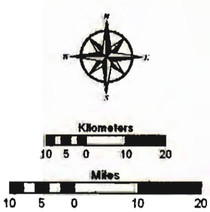


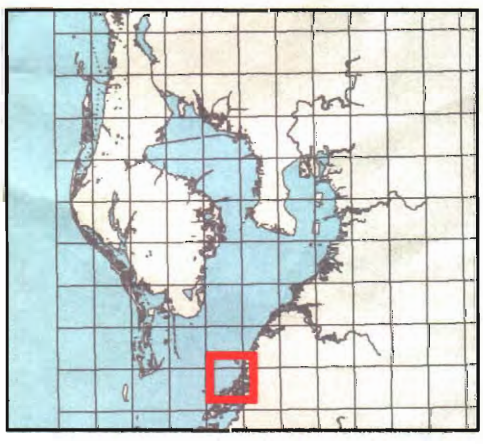


Map 20



Oyster Mapping





Map 21

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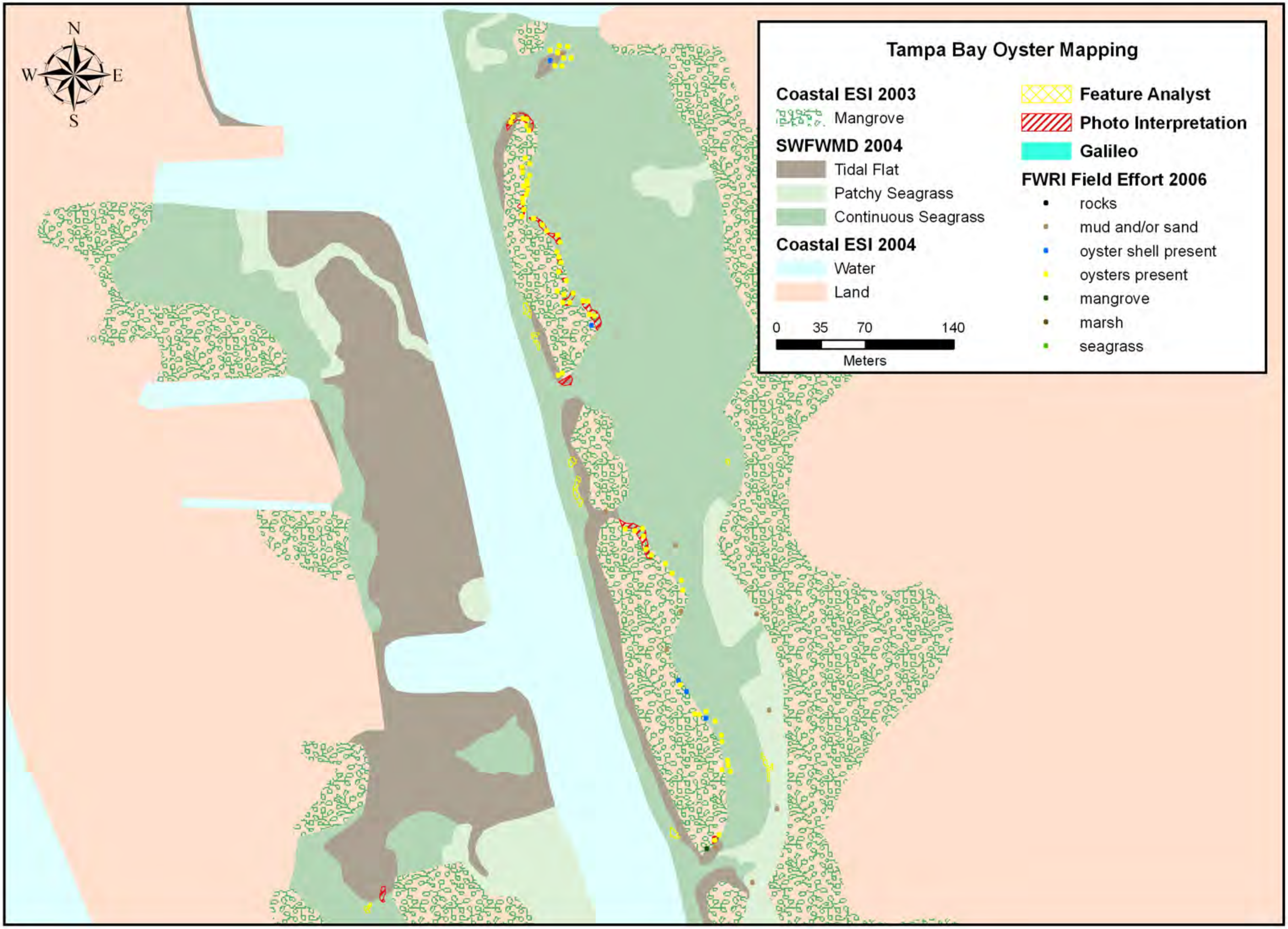
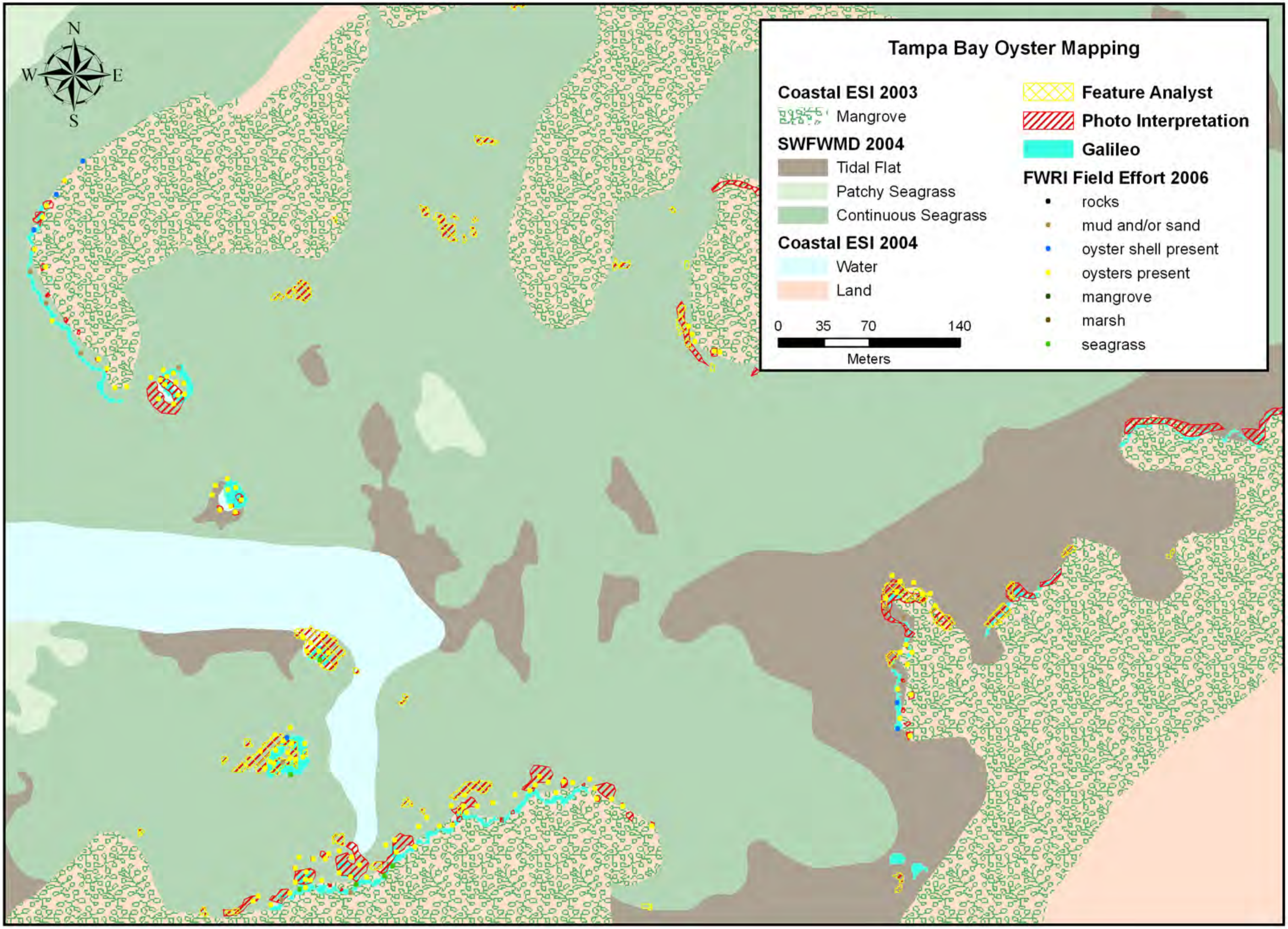
Attachment 6: Field Assessment Maps

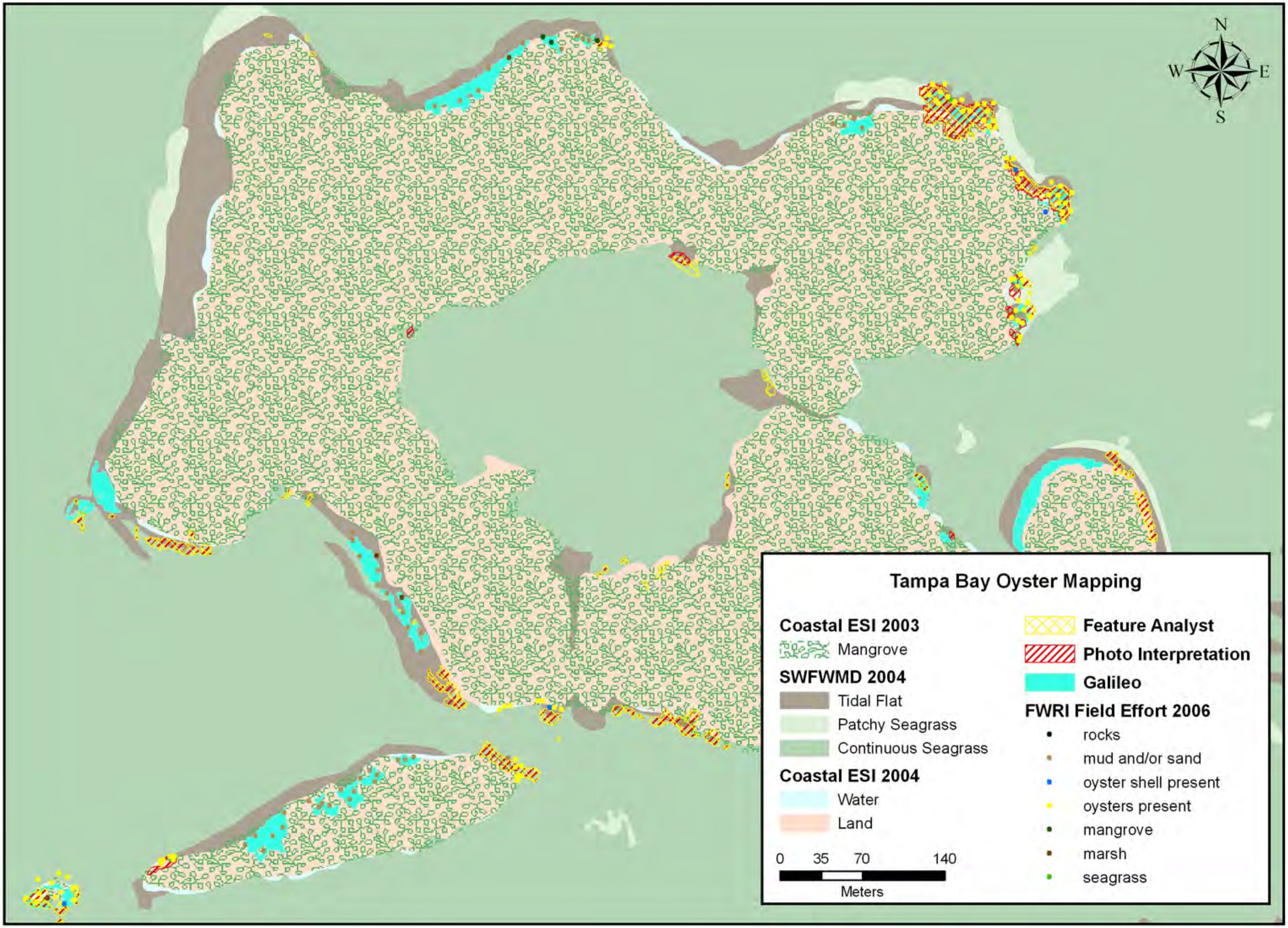
The Narrows


N
W
E
S
Tampa Bay Oyster Mapping
Coastal ESI 2003
Mangrove
SWFWMD 2004
Tidal Flat
Patchy Seagrass
Continuous Seagrass
Coastal ESI 2004
Water
Land
Feature Analyst
Photo Interpretation
Galileo
FWRI Field Effort 2006
rocks
mud and/or sand
oyster shell present
oysters present
mangrove
marsh
seagrass
0
35
70
140
Meters

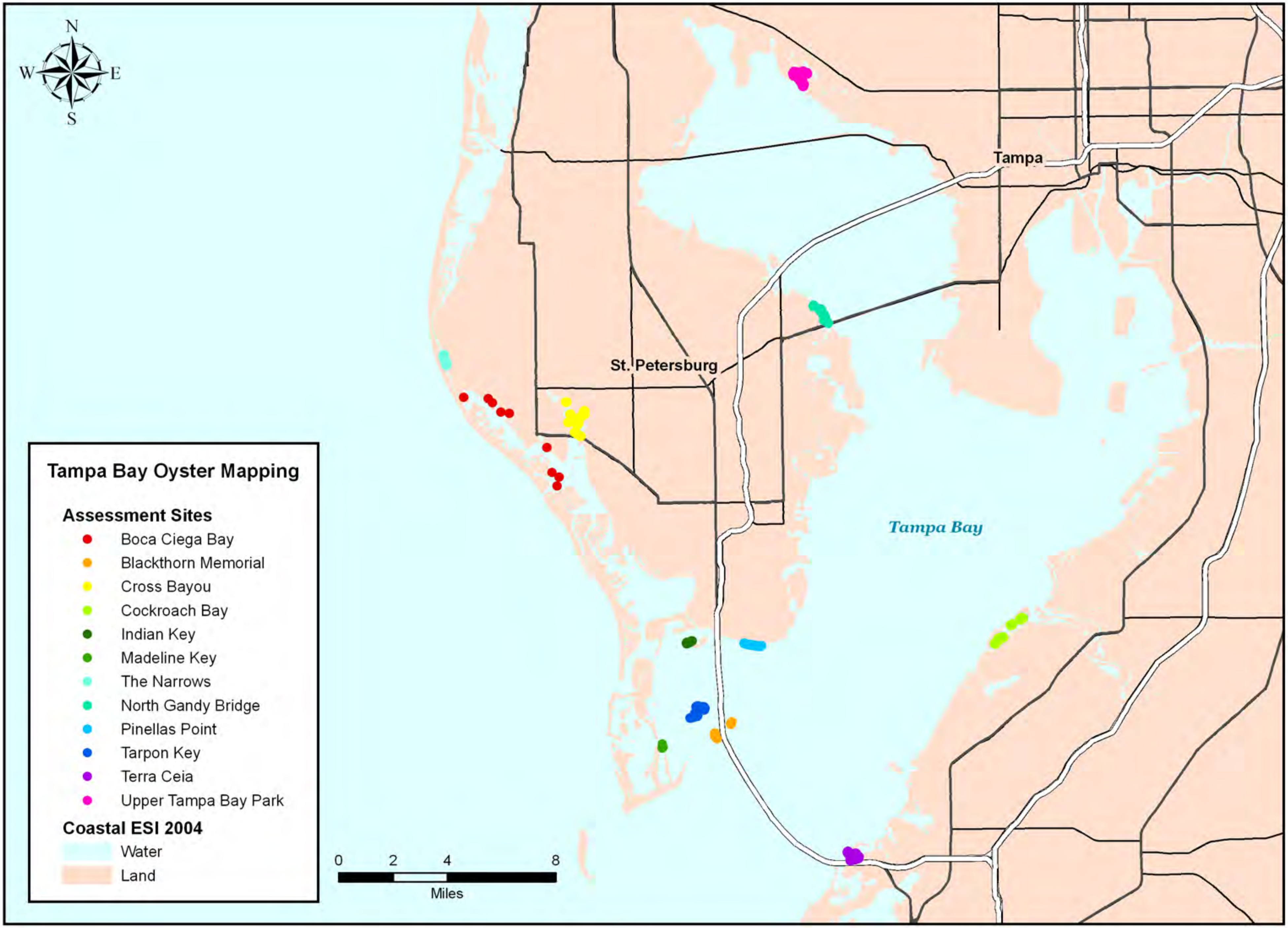
Terra Ceia


N
W
E
S
Tampa Bay Oyster Mapping
Coastal ESI 2003
Mangrove
SWFWMD 2004
Tidal Flat
Patchy Seagrass
Continuous Seagrass
Coastal ESI 2004
Water
Land
0 35 70 140
Meters
Feature Analyst
Photo Interpretation
Galileo
FWRI Field Effort 2006
rocks
mud and/or sand
oyster shell present
oysters present
mangrove
marsh
seagrass

Tarpon Key



N
W
E
S
Tampa Bay Oyster Mapping
Coastal ESI 2003
Mangrove
SWFWMD 2004
Tidal Flat
Patchy Seagrass
Continuous Seagrass
Coastal ESI 2004
Water
Land
Feature Analyst
Photo Interpretation
Galileo
FWRI Field Effort 2006
rocks
mud and/or sand
oyster shell present
oysters present
mangrove
marsh
seagrass
0
35
70
140
Meters



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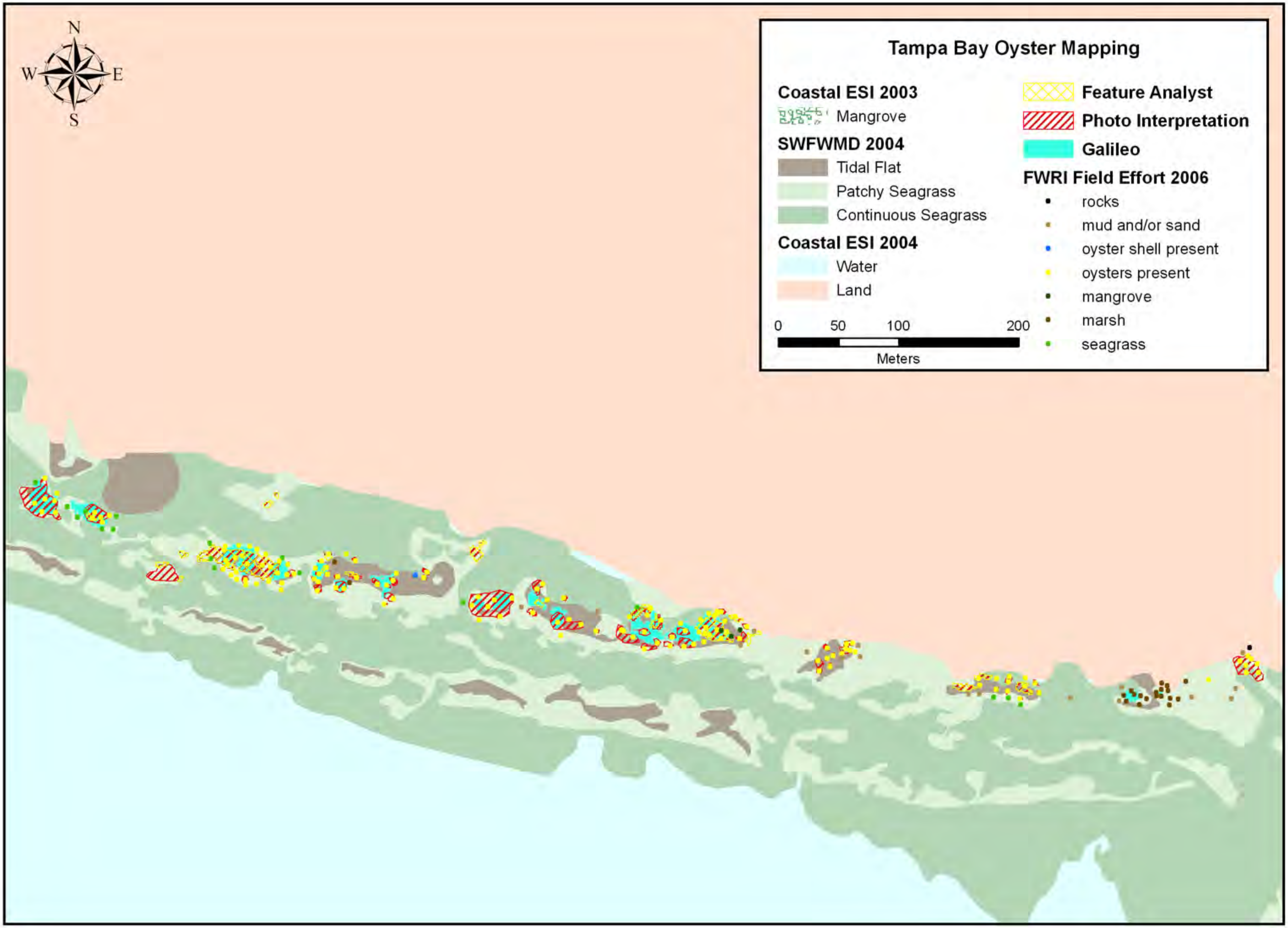
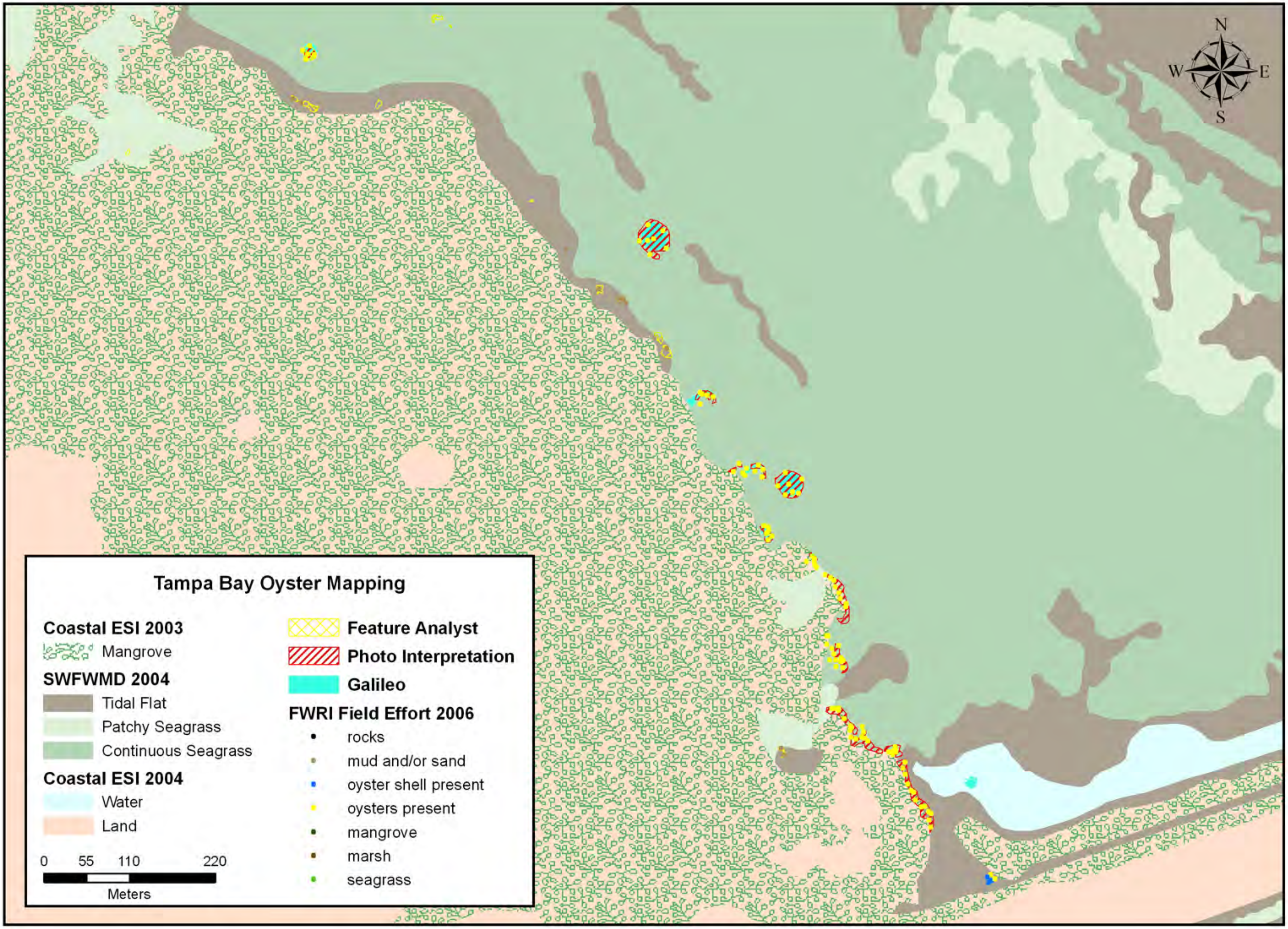
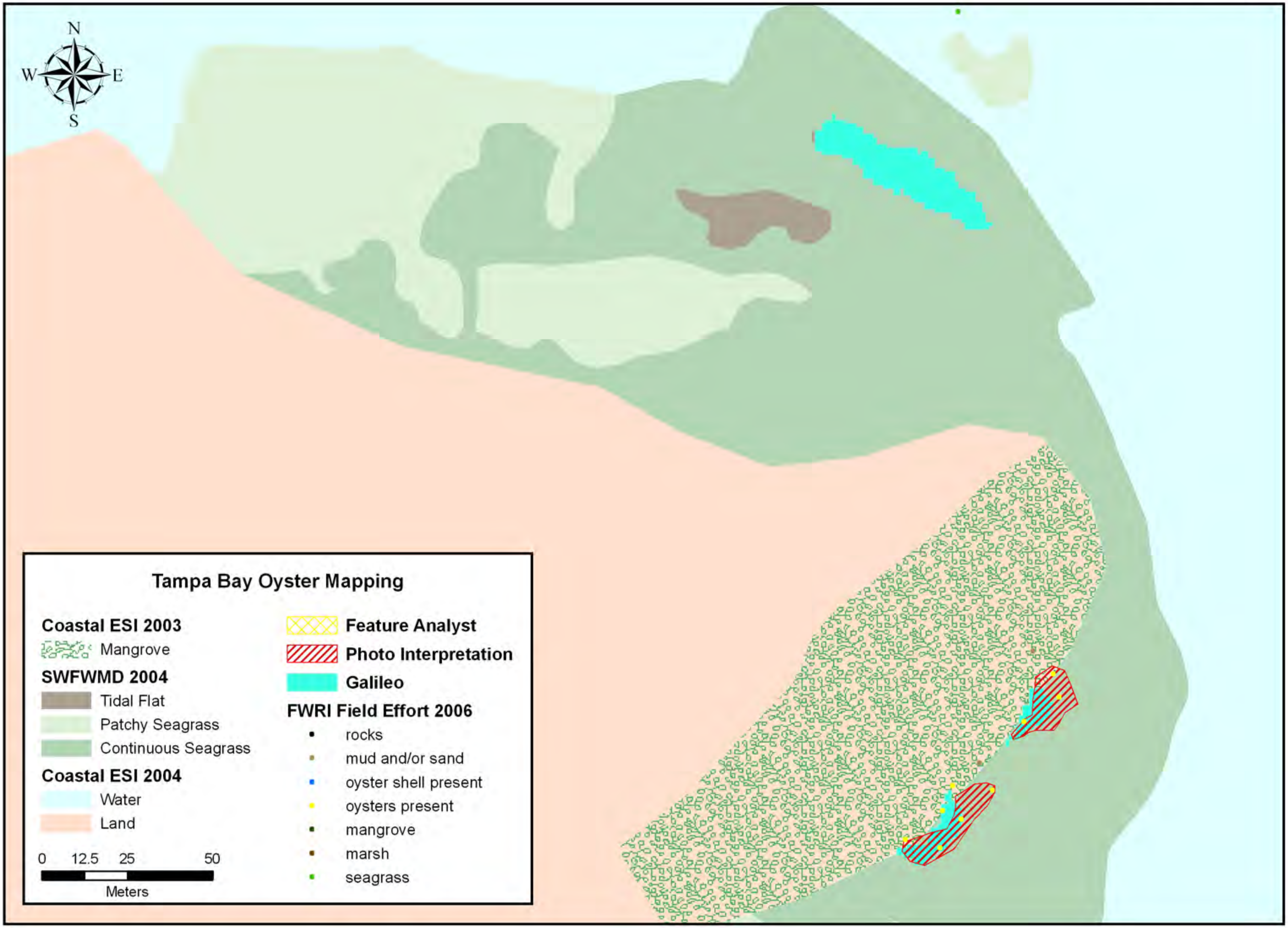
Pinellas Point



North Gandy Bridge



Madeline Key



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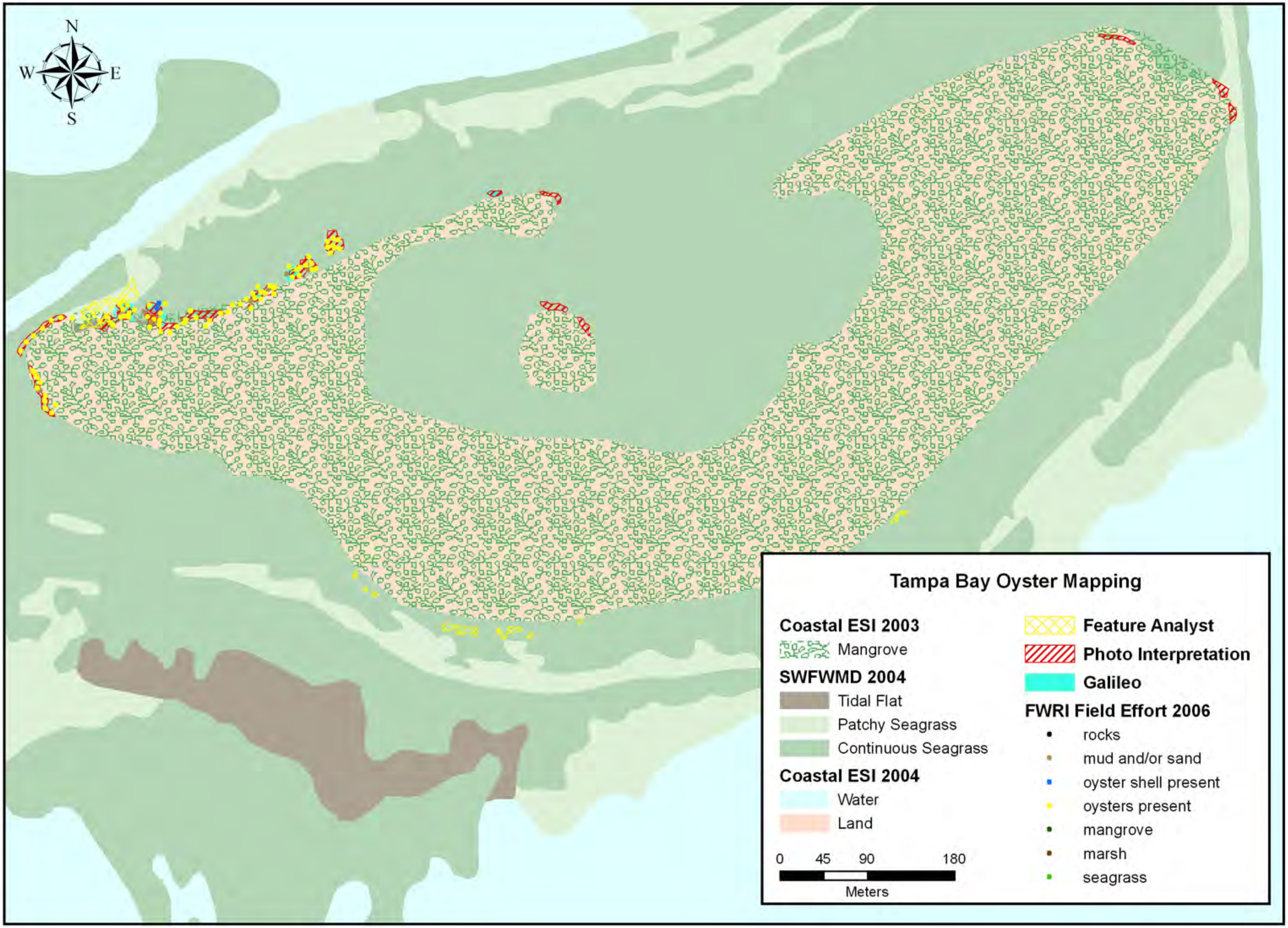
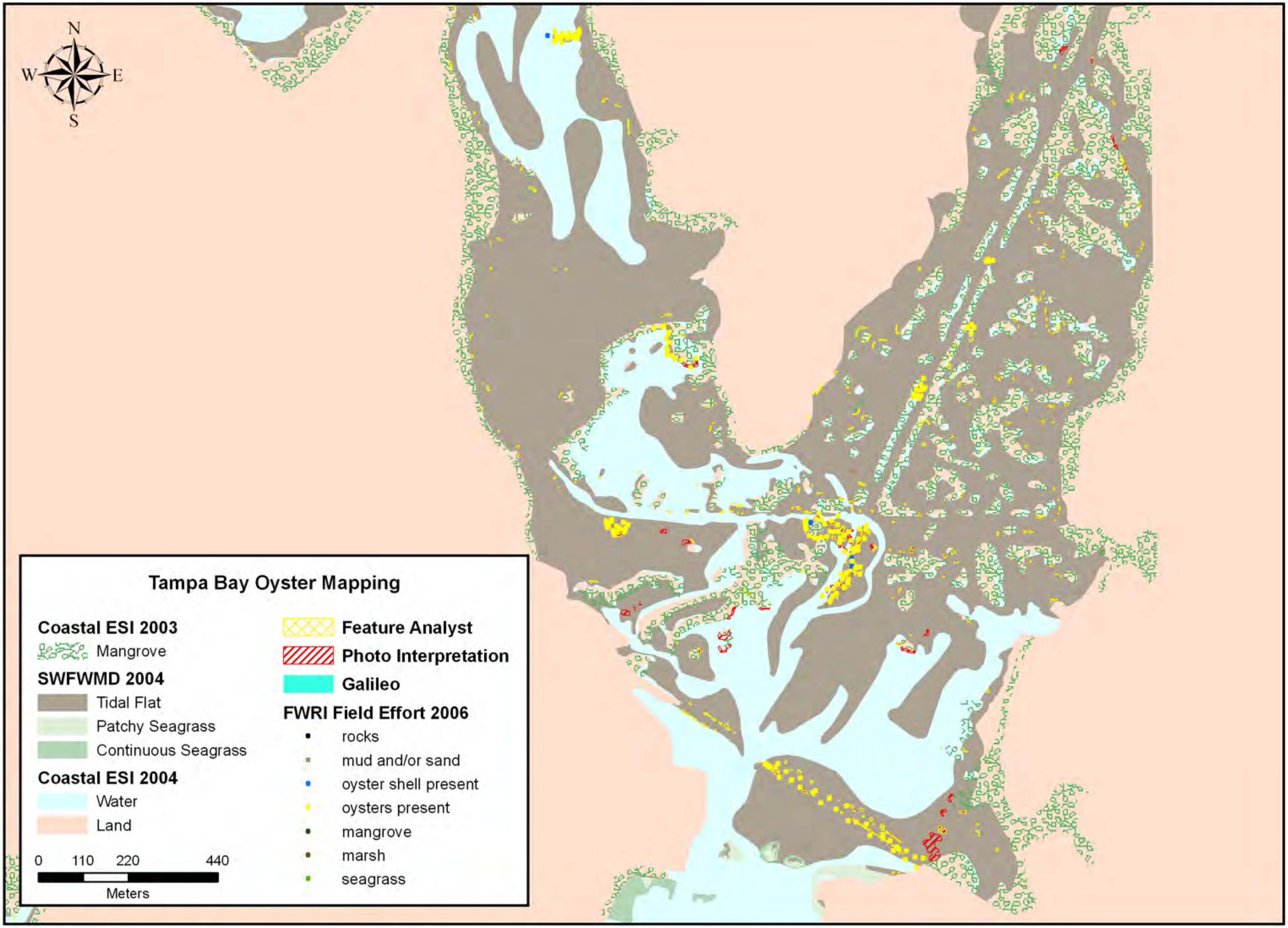
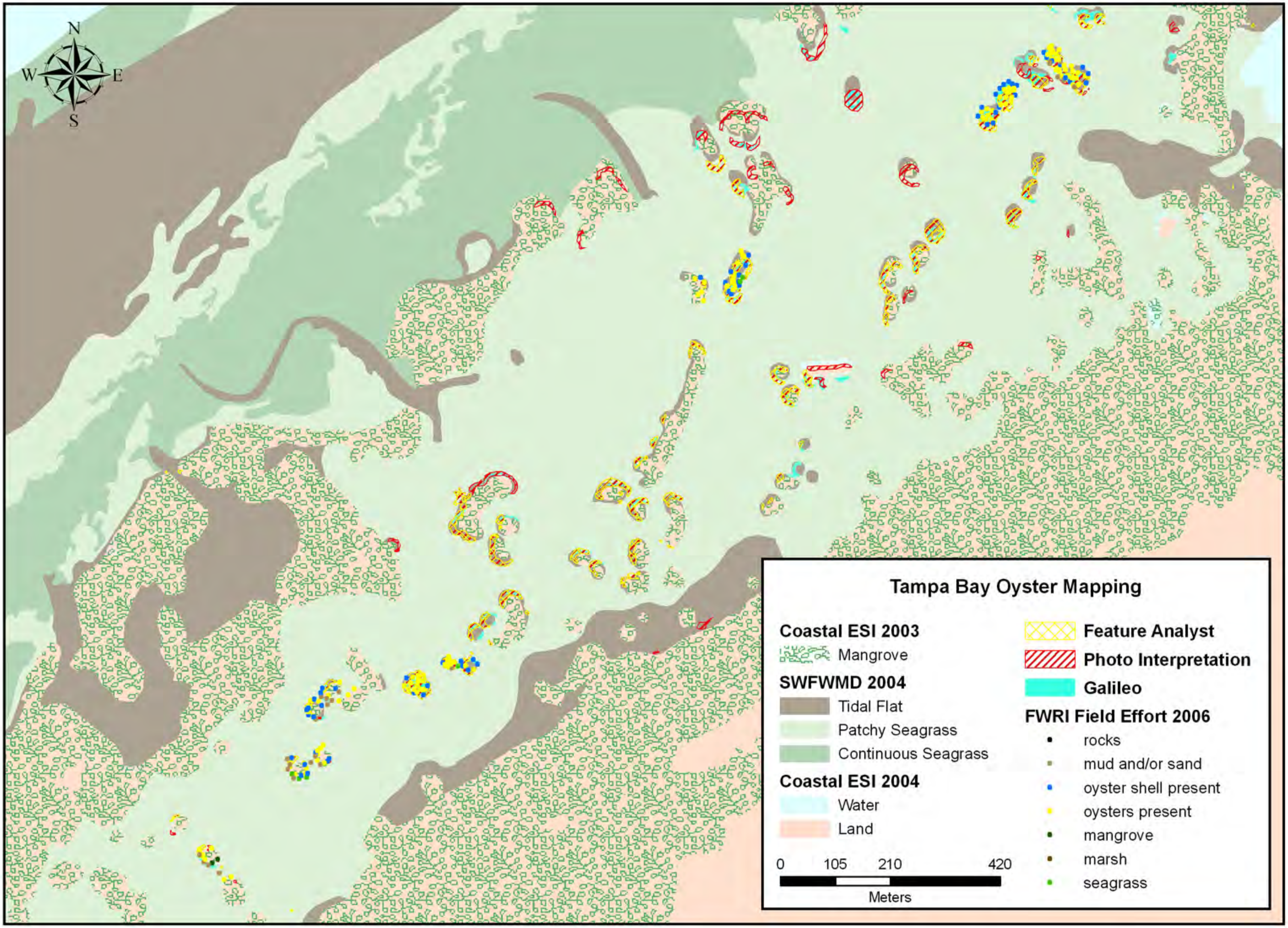
Indian Key


N
S
E
W
Tampa Bay Oyster Mapping
Coastal ESI 2003
Mangrove
SWFWMD 2004
Tidal Flat
Patchy Seagrass
Continuous Seagrass
Coastal ESI 2004
Water
Land
Feature Analyst
Photo Interpretation
Galileo
FWRI Field Effort 2006
rocks
mud and/or sand
oyster shell present
oysters present
mangrove
marsh
seagrass
0 45 90 180
Meters

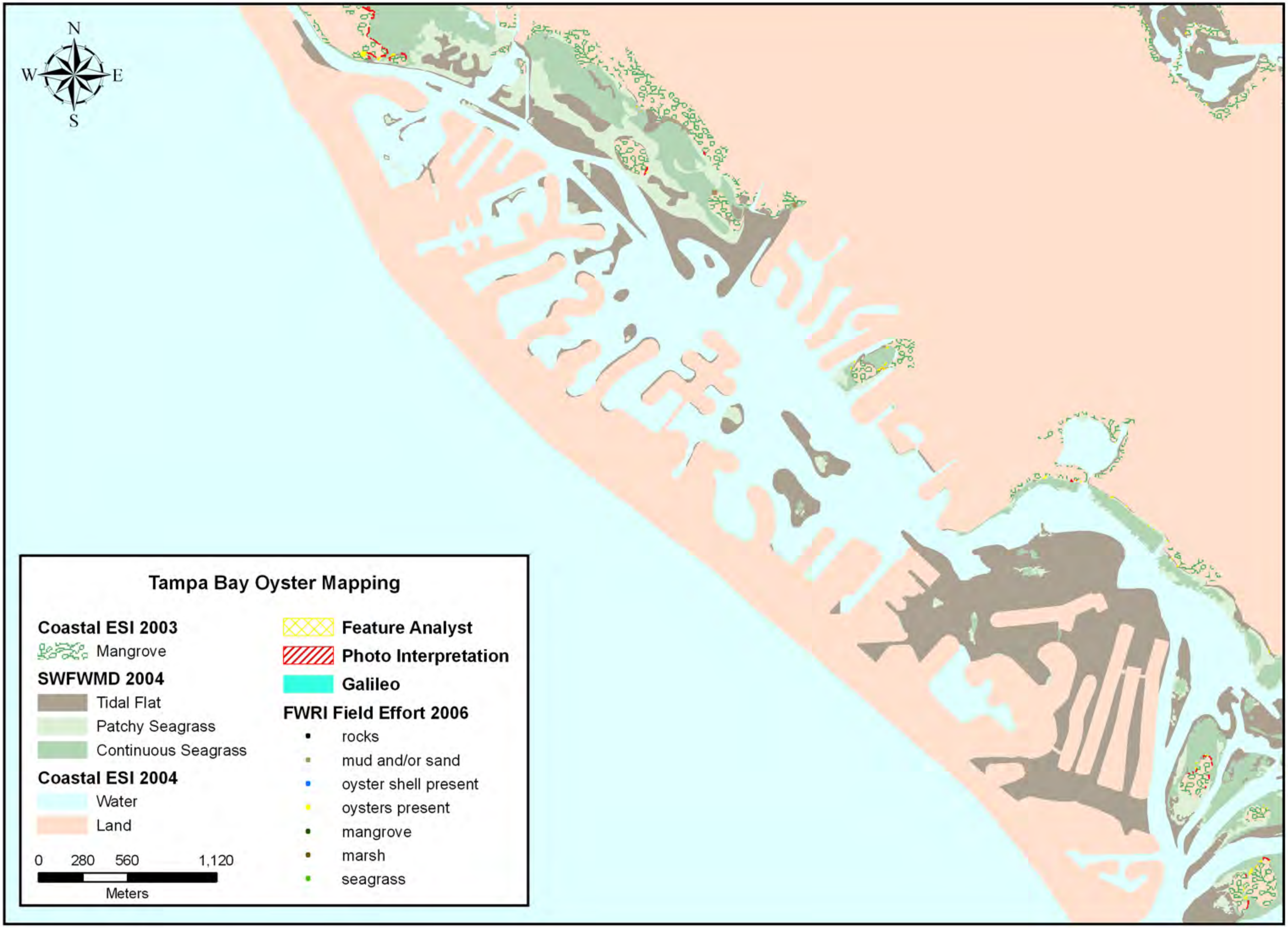
Cross Bayou


N
W
E
S
Tampa Bay Oyster Mapping
Coastal ESI 2003
Mangrove
SWFWMD 2004
Tidal Flat
Patchy Seagrass
Continuous Seagrass
Coastal ESI 2004
Water
Land
0 110 220 440
Meters
Feature Analyst
Photo Interpretation
Galileo
FWRI Field Effort 2006
rocks
mud and/or sand
oyster shell present
oysters present
mangrove
marsh
seagrass

Cockroach Bay



Boca Ciega Bay



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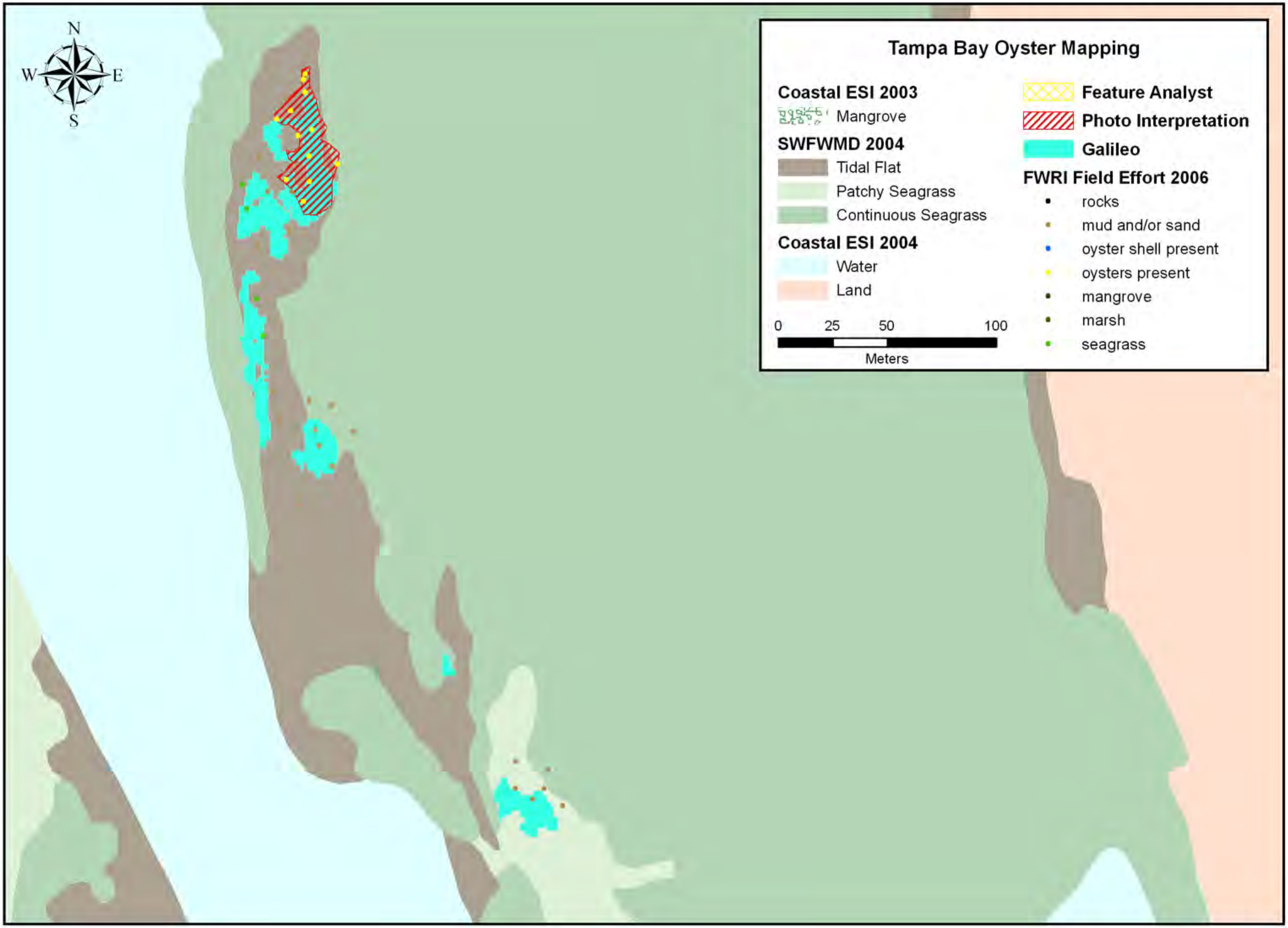
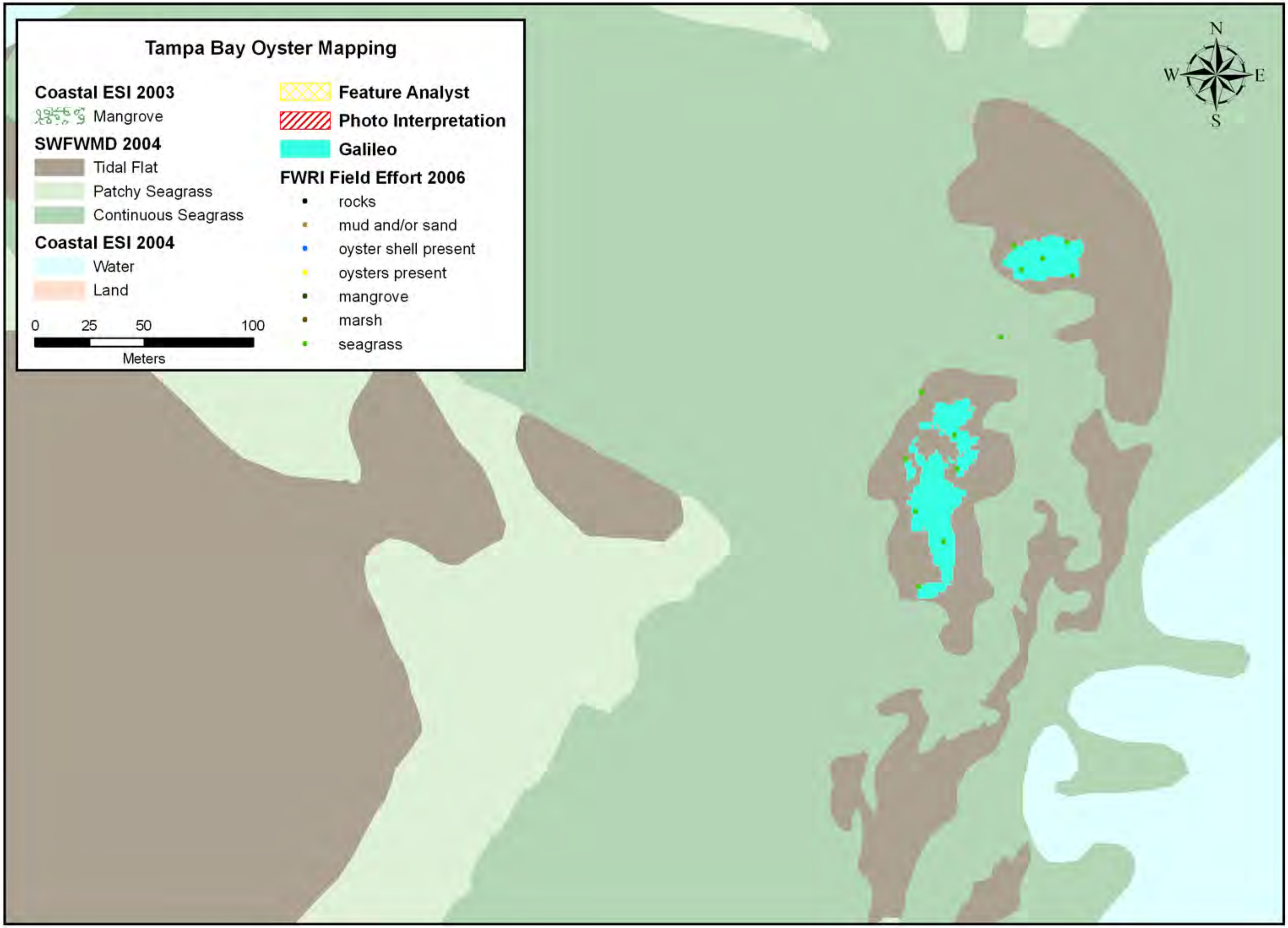
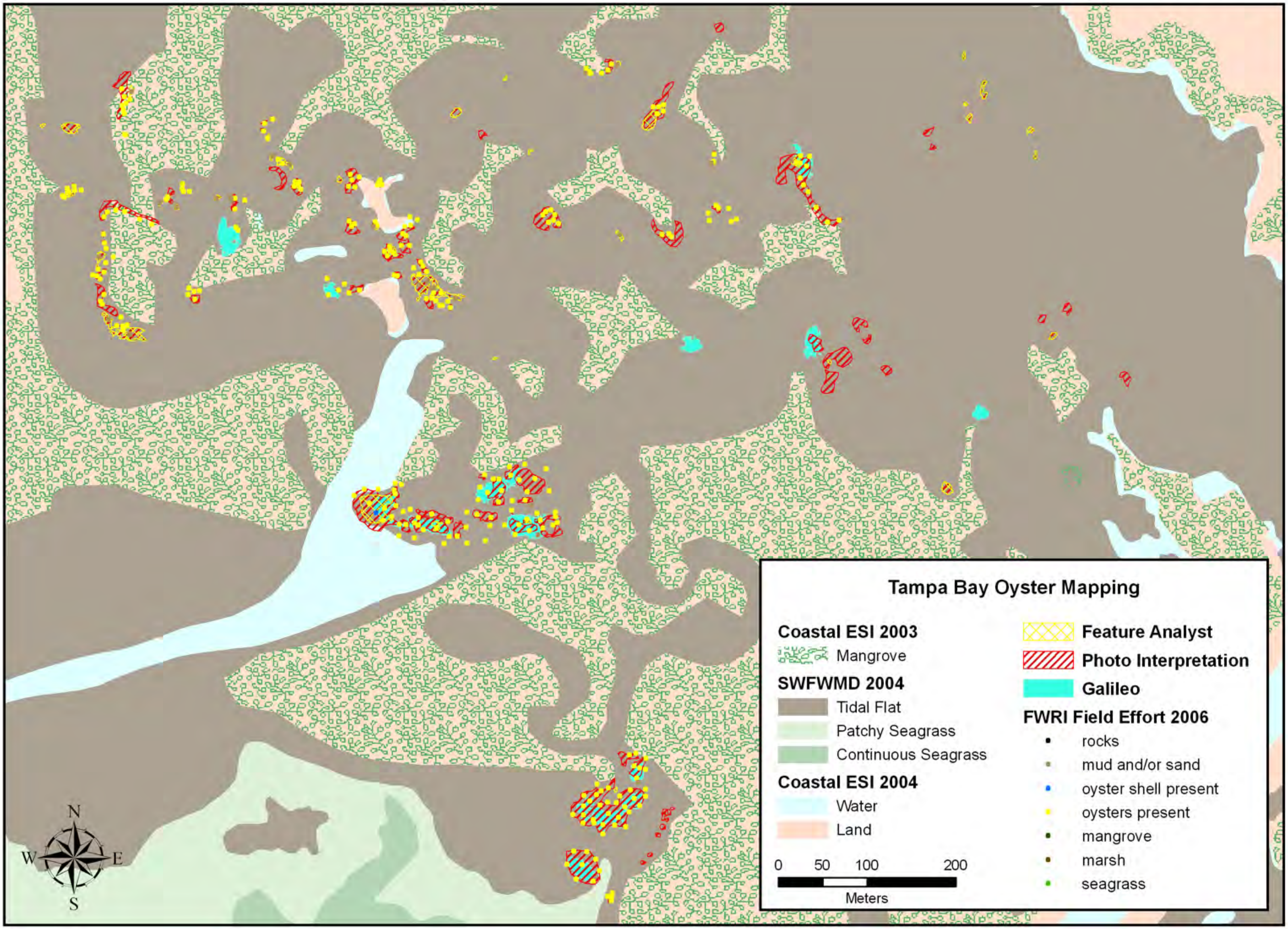
Blackthorn Memorial West



Blackthorn Memorial East

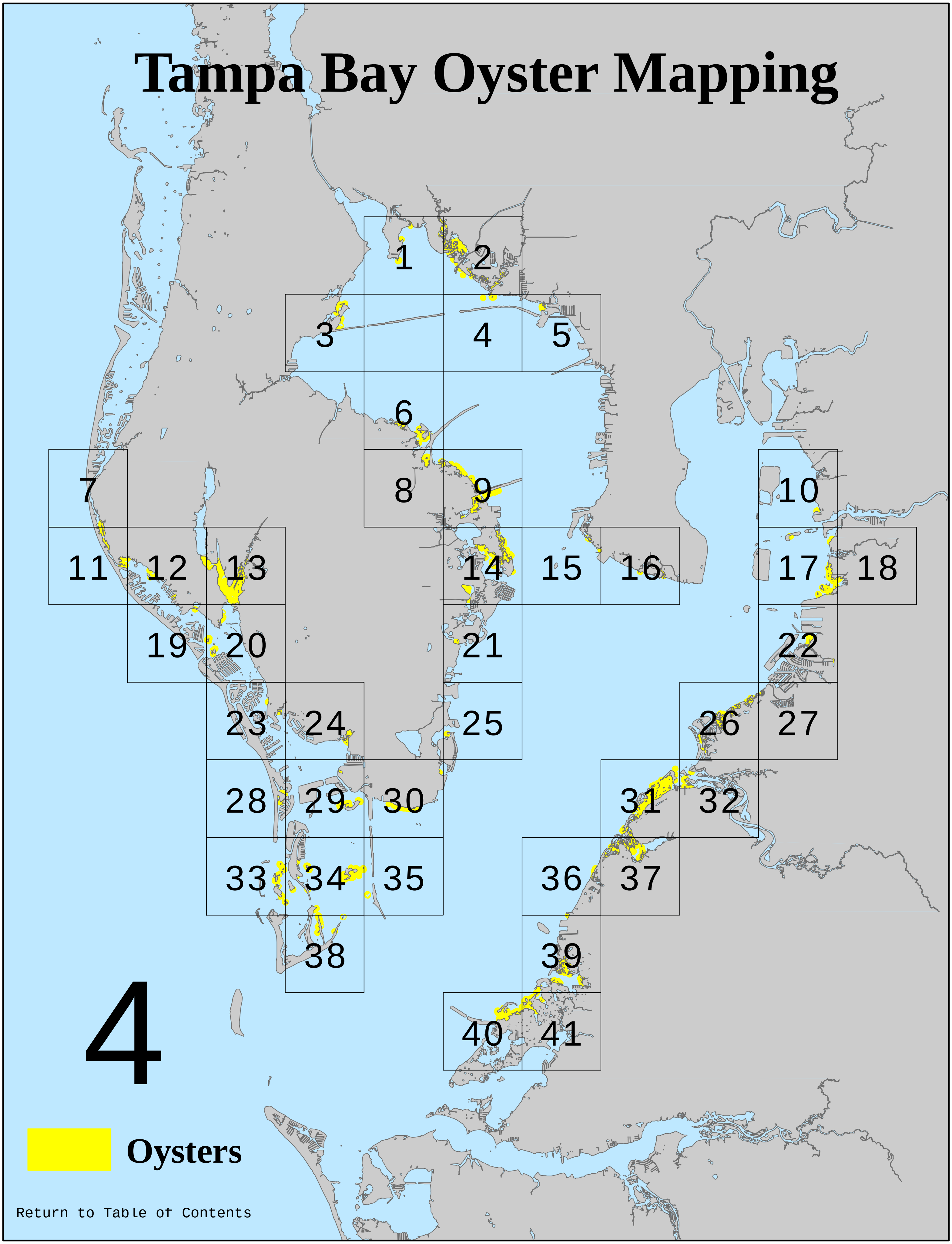


Upper Tampa Bay Park



Attachment 7: Final Maps

Tampa Bay Oyster Mapping



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See Map 41

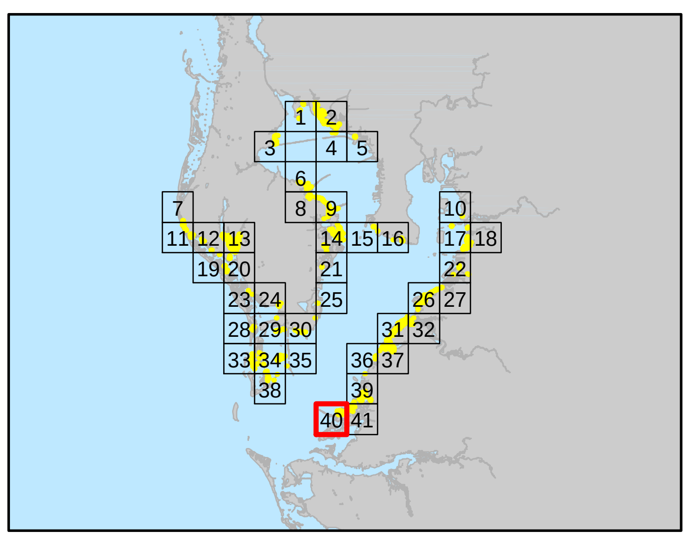
Tampa Bay Oyster Mapping

4

Oysters

20 10 0 20

Miles



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See Map 36

See Map 41

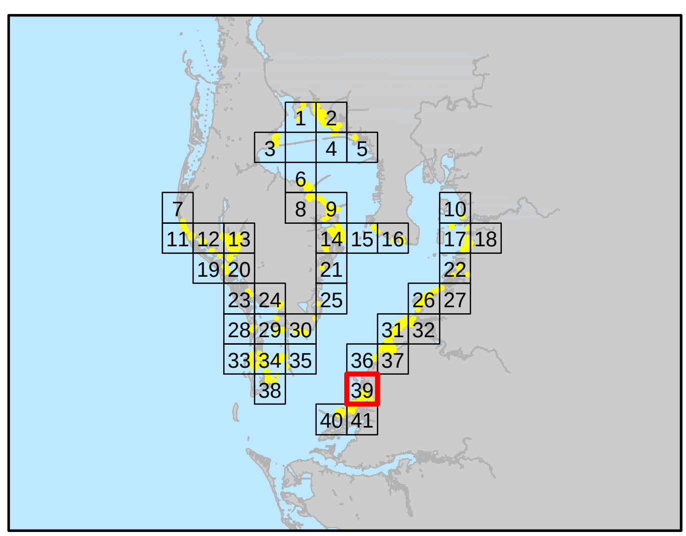
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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See Map 34

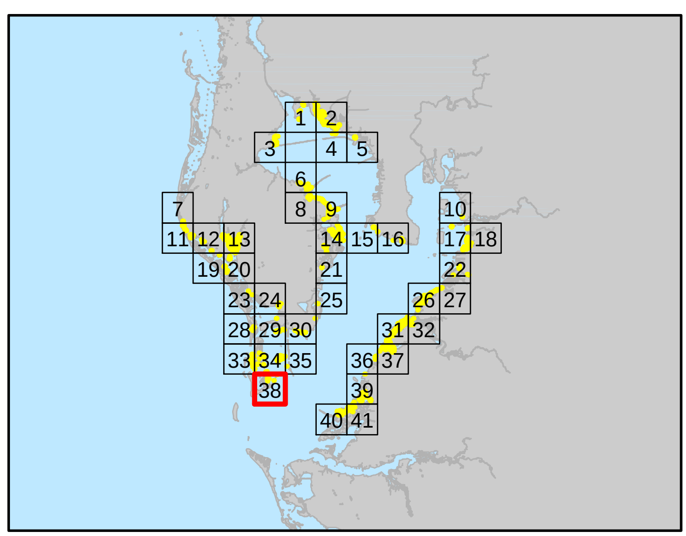
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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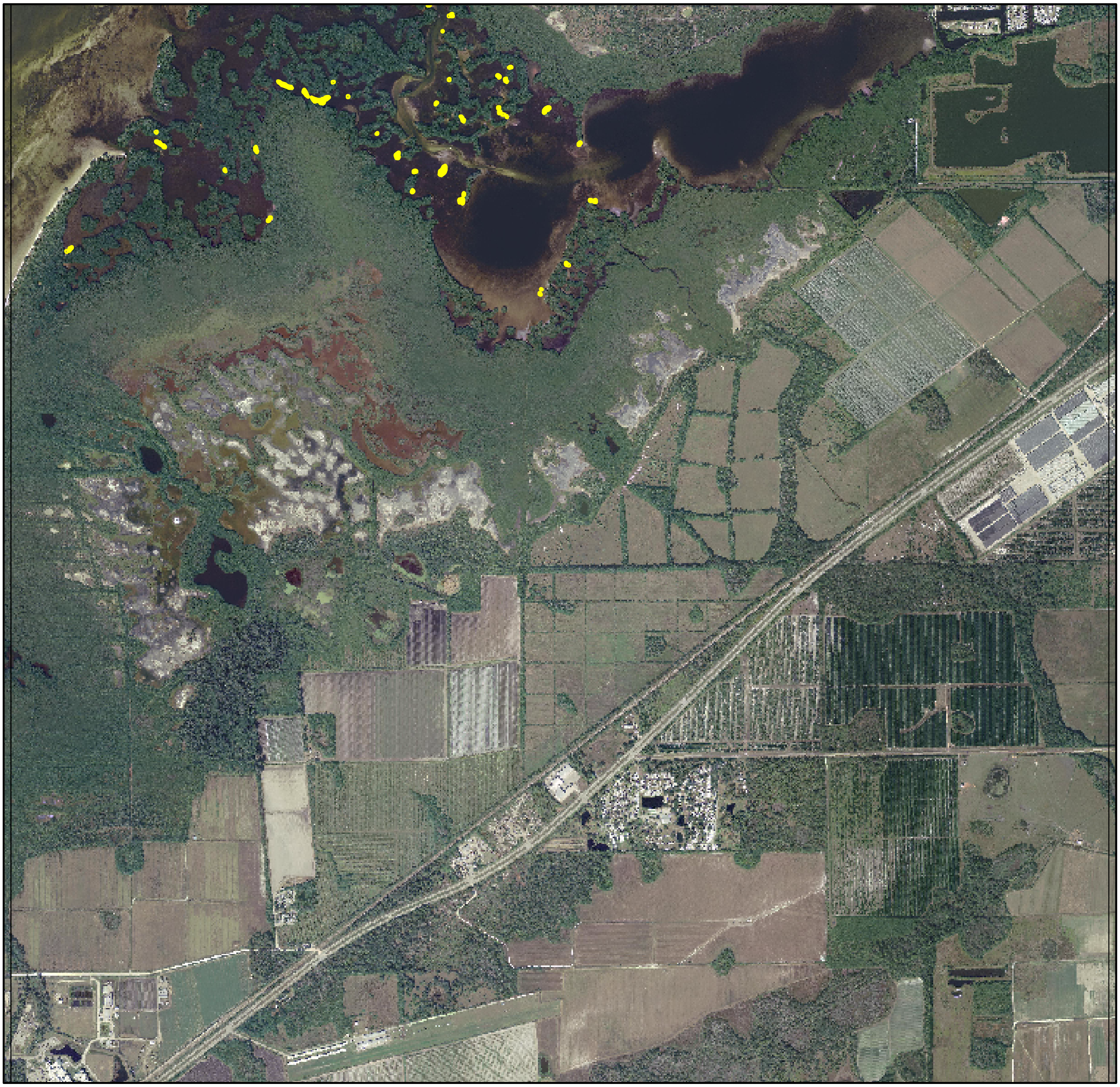
See Map 31

See Map 36



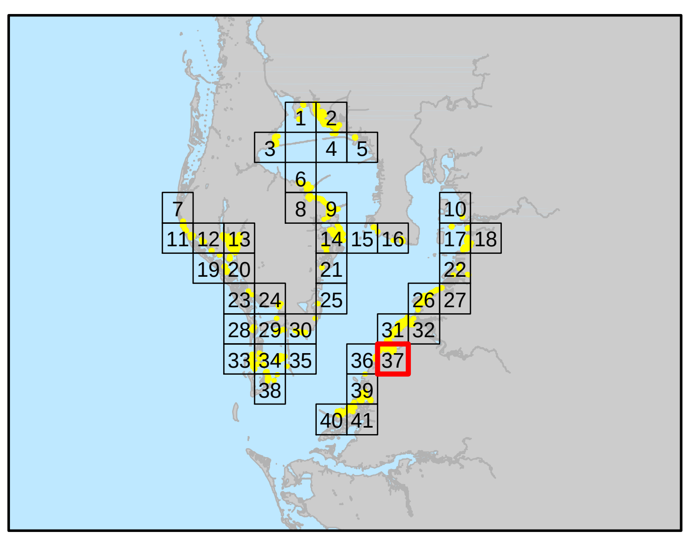
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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See Map 37

See Map 39

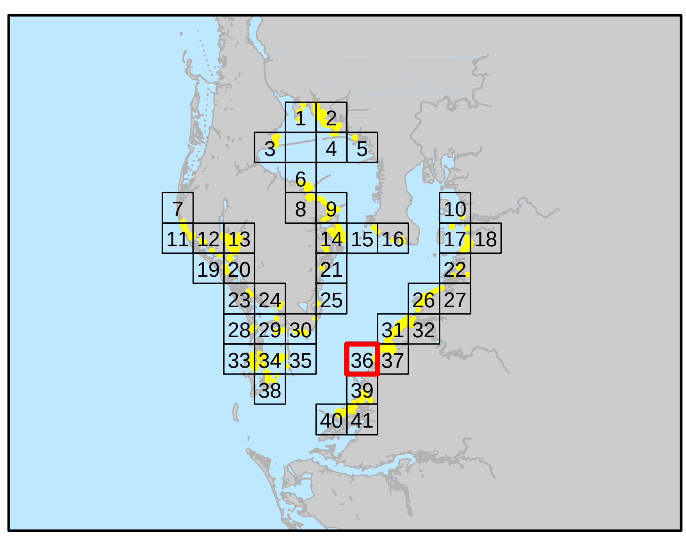
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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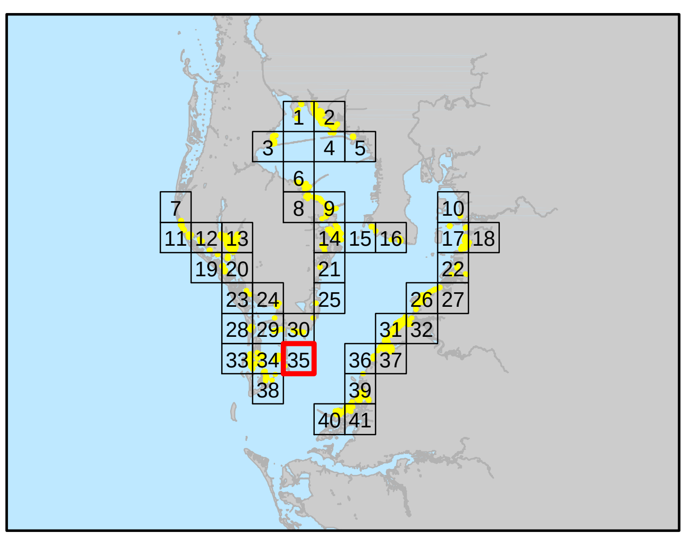
See Map 30

See Map 34

Tampa Bay Oyster Mapping

Oysters

4



20 10 0 20

Miles

Return to Index Map Return to Table of Contents

See Map 29

See Map 33

See Map 35

See Map 38

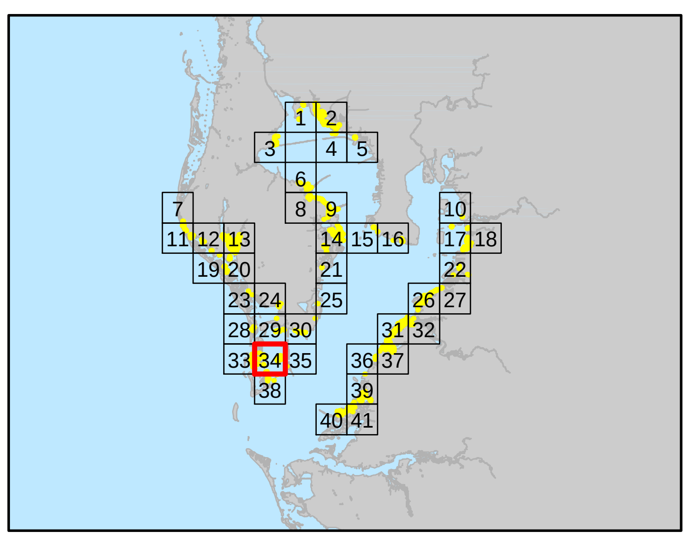
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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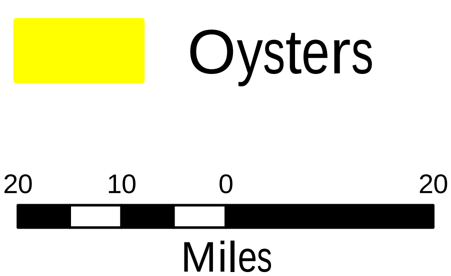
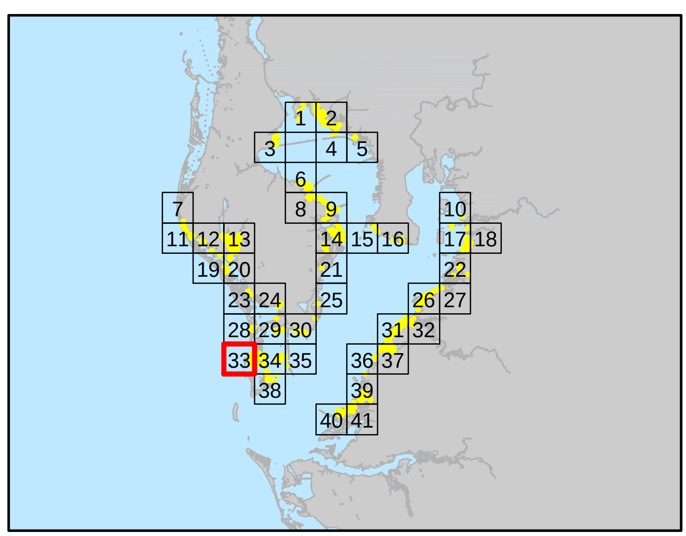
See Map 28

See Map 34

Tampa Bay Oyster Mapping

4





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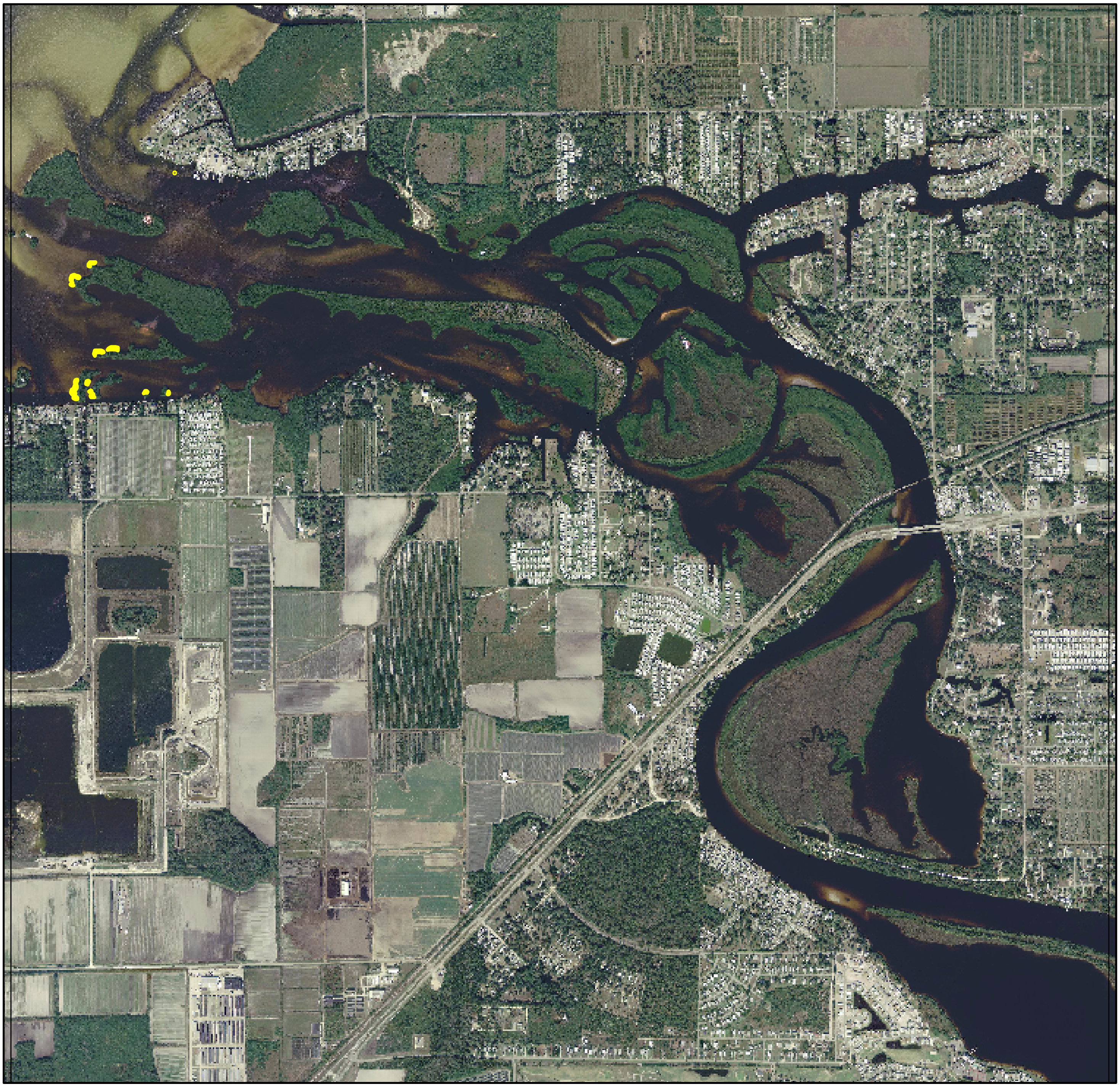
See Map 26

See Map 31



Tampa Bay Oyster Mapping

Oysters

4

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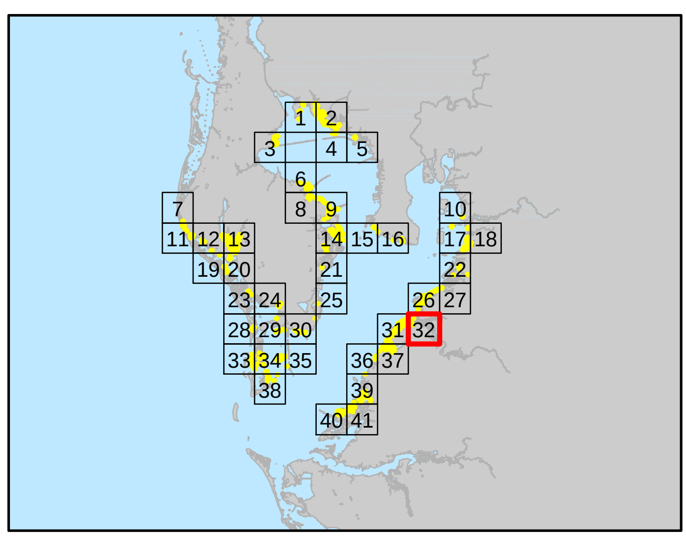
Miles



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See Map 32

See Map 37

Tampa Bay Oyster Mapping

Oysters

4

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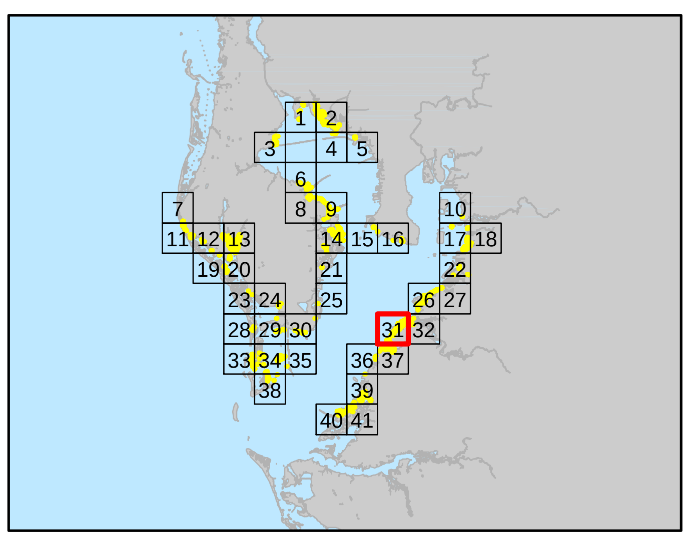
Miles



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See Map 29

See Map 35

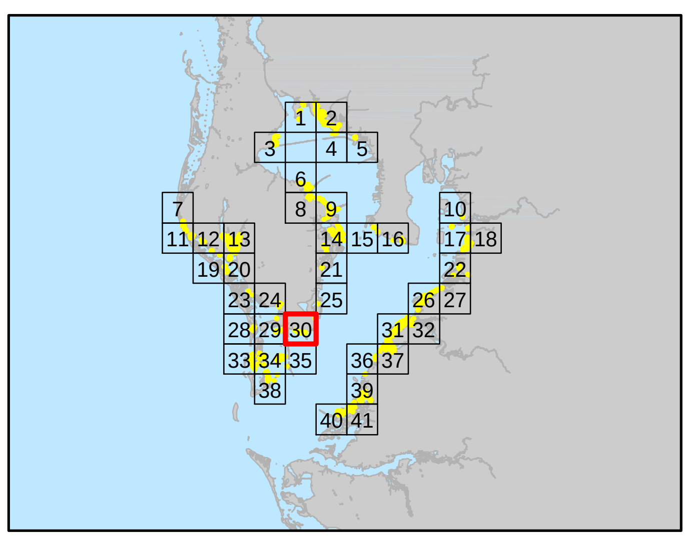
Tampa Bay Oyster Mapping

4

Oysters

20 10 0 20

Miles



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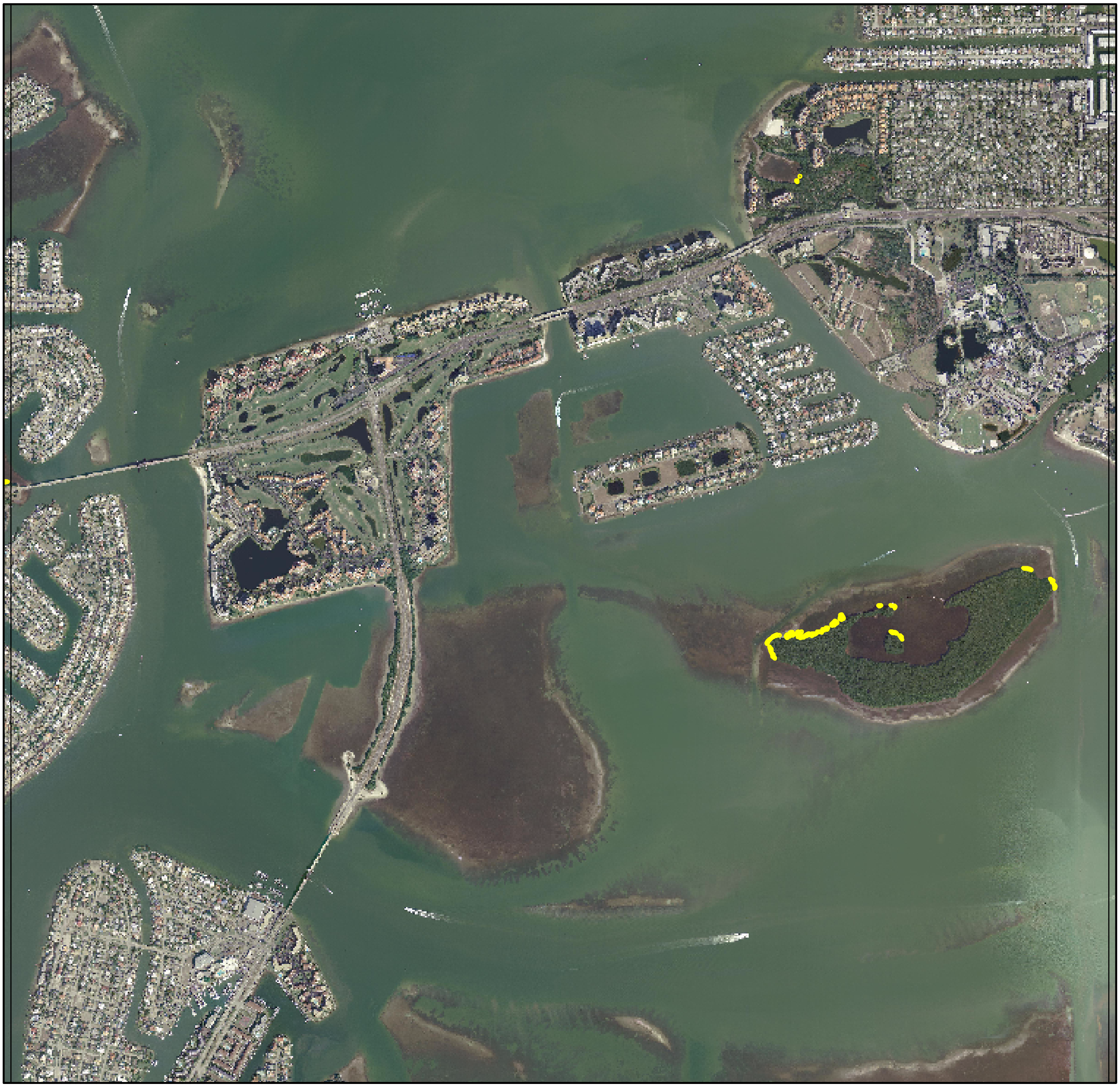
See Map 28



See Map 30

See Map 34

Tampa Bay Oyster Mapping

Oysters

4

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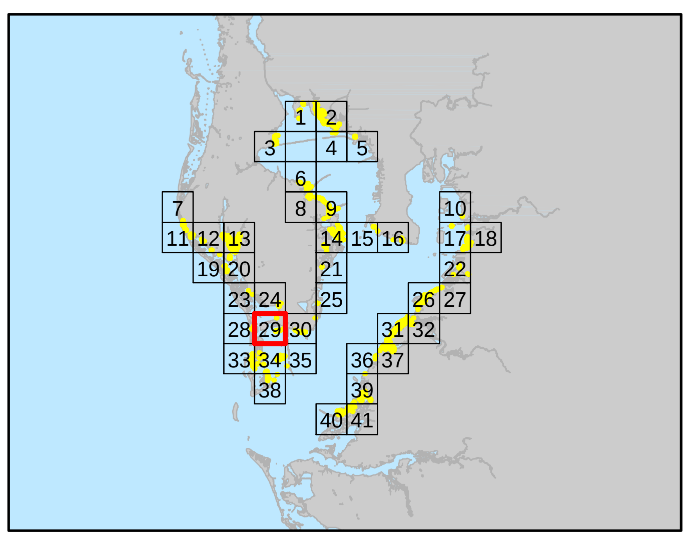
Miles



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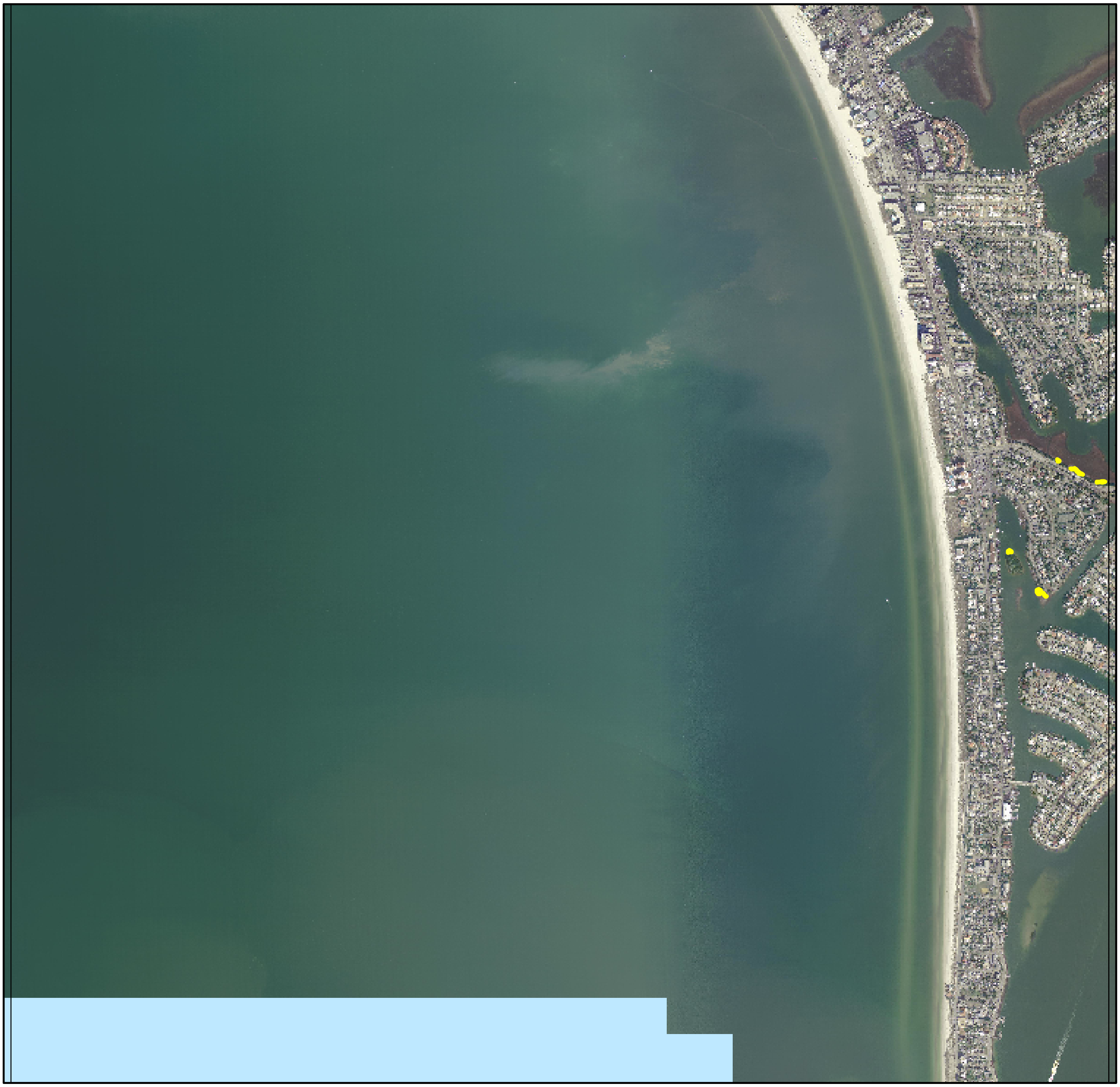
See Map 23



See Map 29

See Map 33

Tampa Bay Oyster Mapping

4

Oysters

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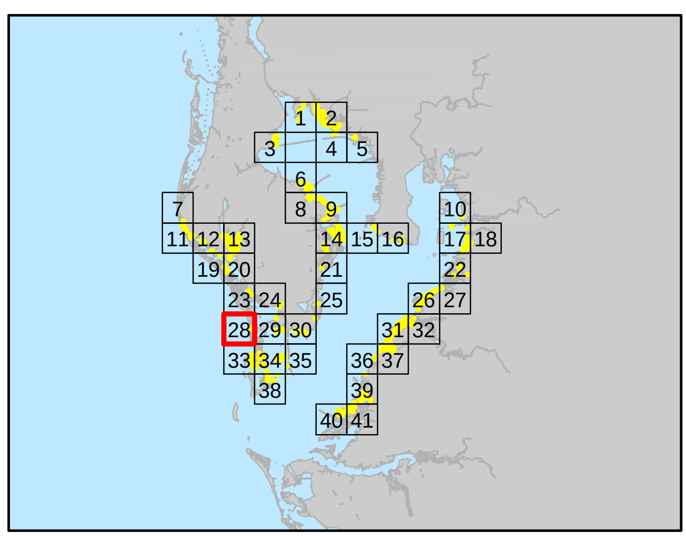
Miles



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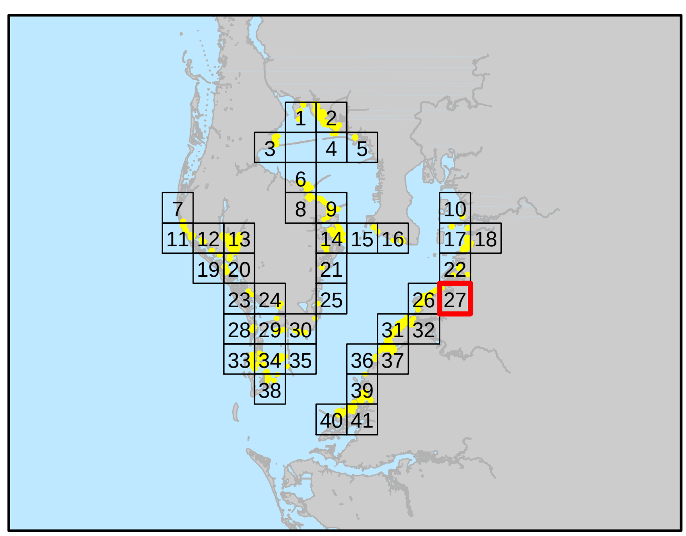
See Map 22

See Map 26

Tampa Bay Oyster Mapping

Oysters

4



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Miles

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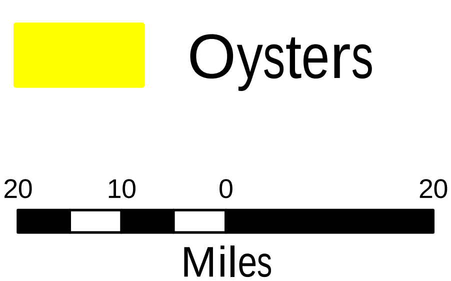
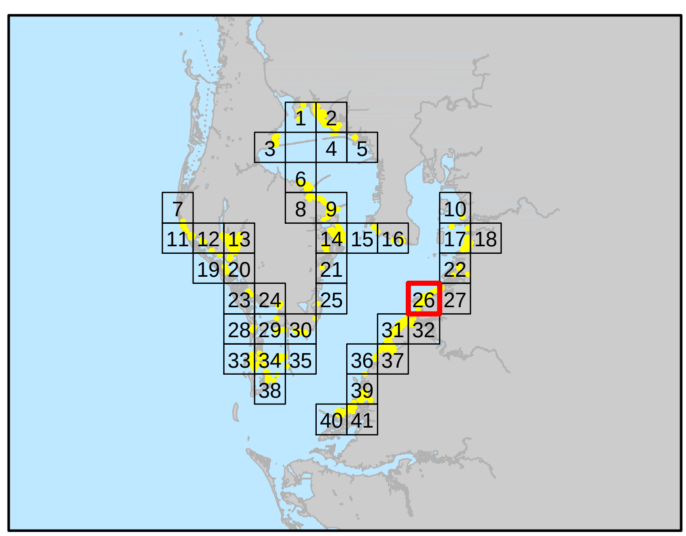
See Map 27
See Map 32

Tampa Bay Oyster Mapping

4





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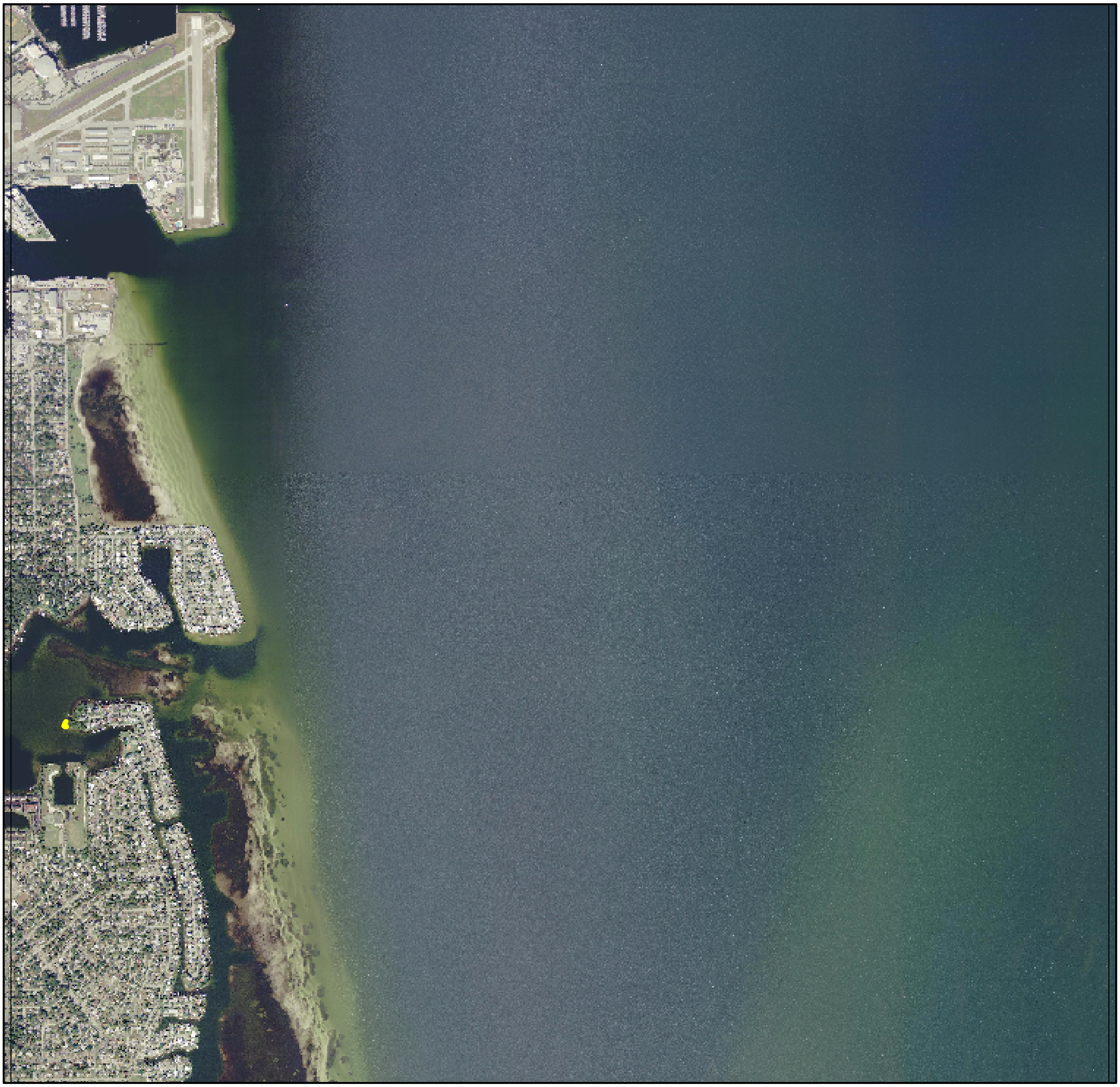

Tampa Bay Oyster Mapping

Oysters

4

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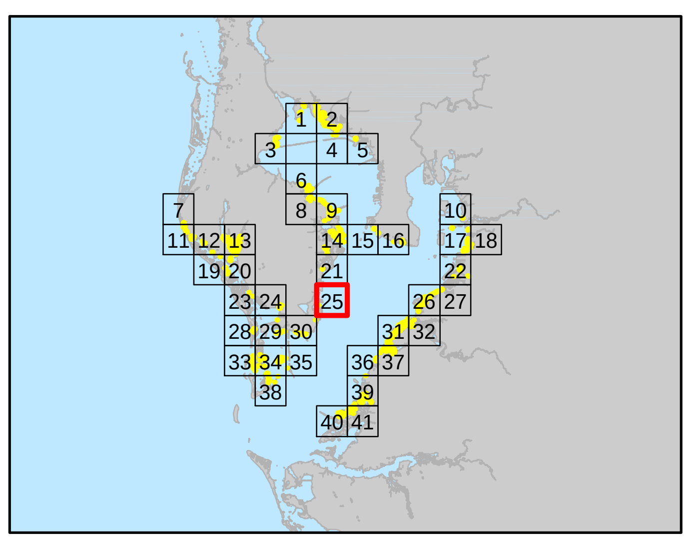
Miles



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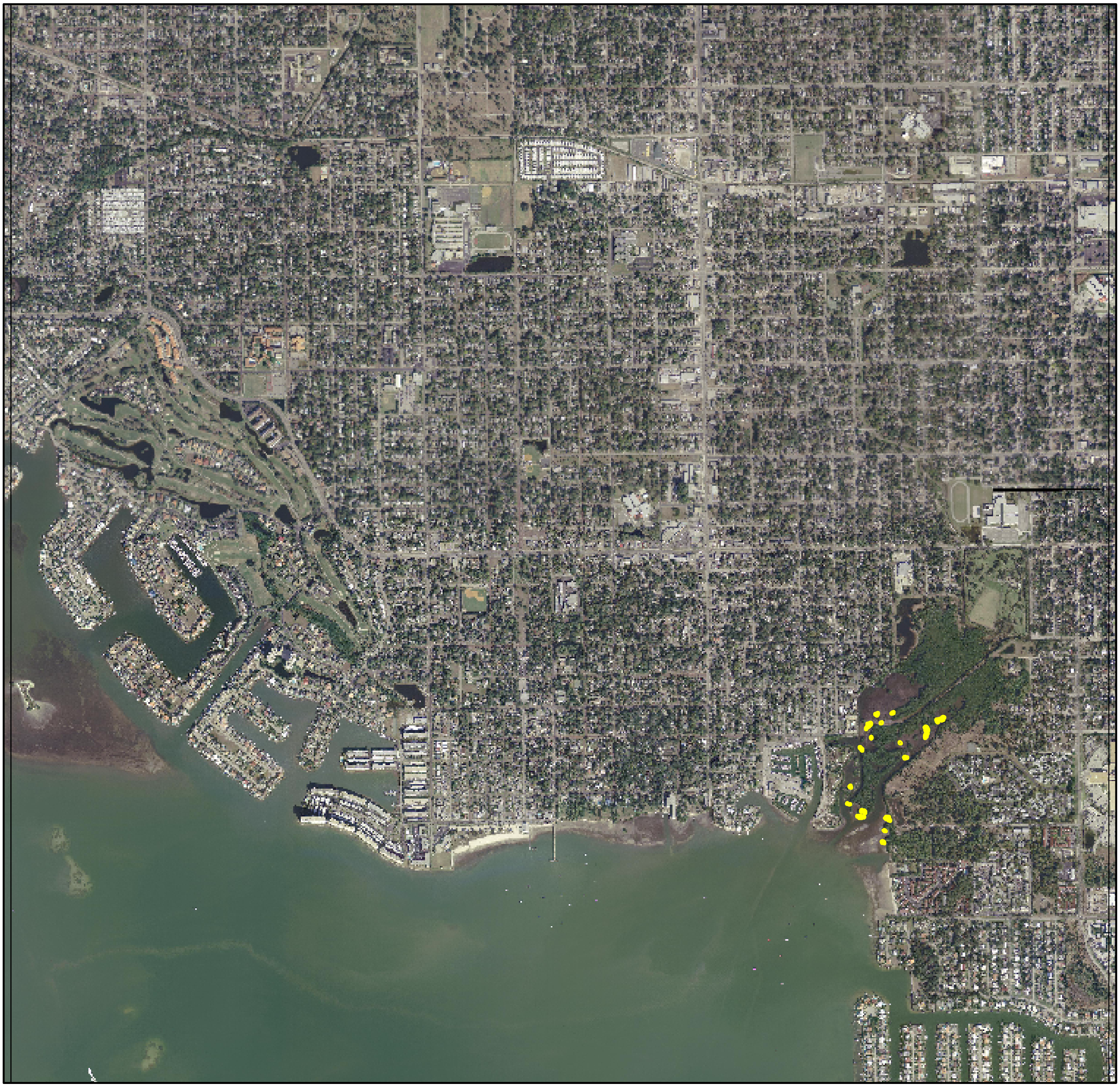


See Map 29

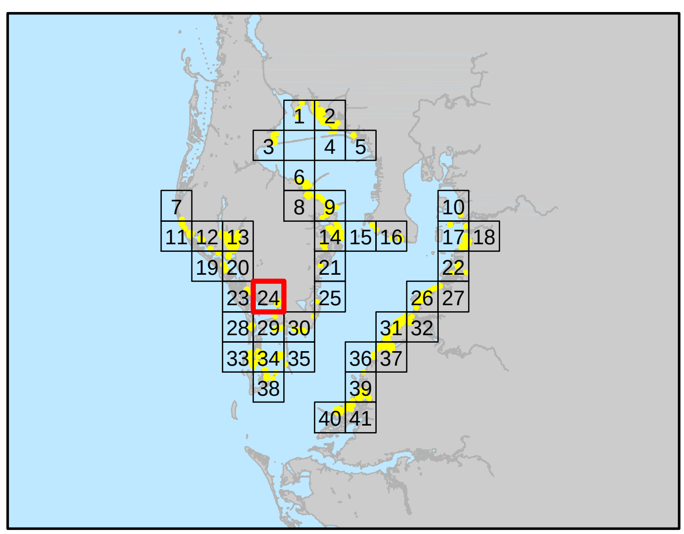
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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See Map 20

See Map 24

See Map 28

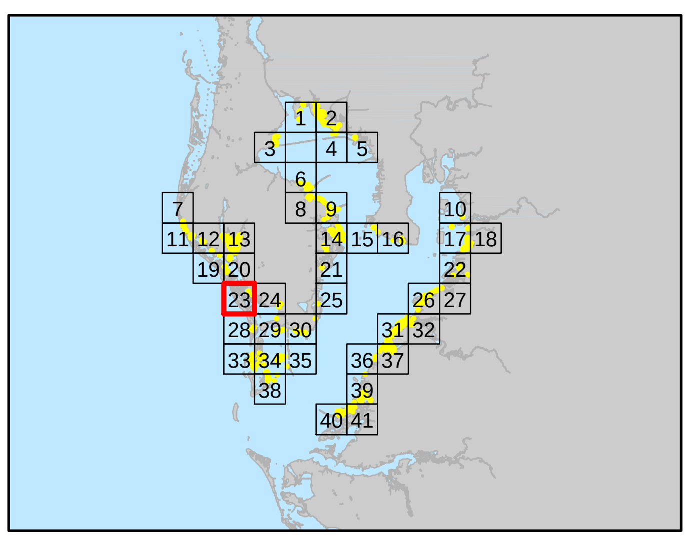
Tampa Bay Oyster Mapping

4

Oysters

20 10 0 20

Miles



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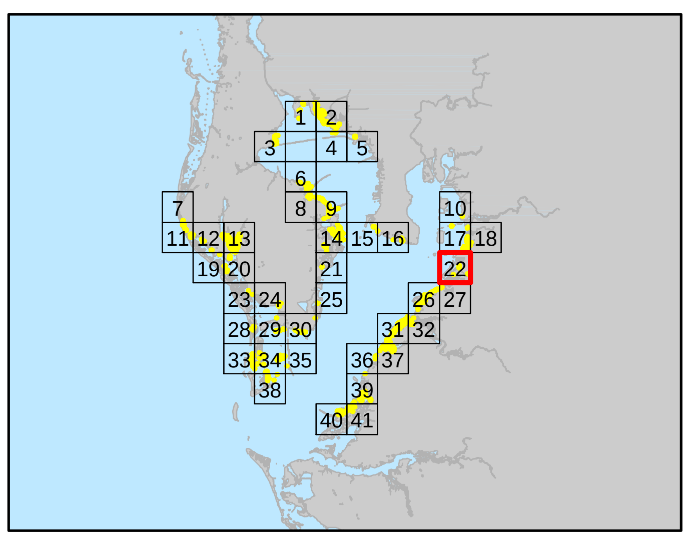
See Map 17

See Map 27

Tampa Bay Oyster Mapping



Oysters

4

20 10 0 20

Miles

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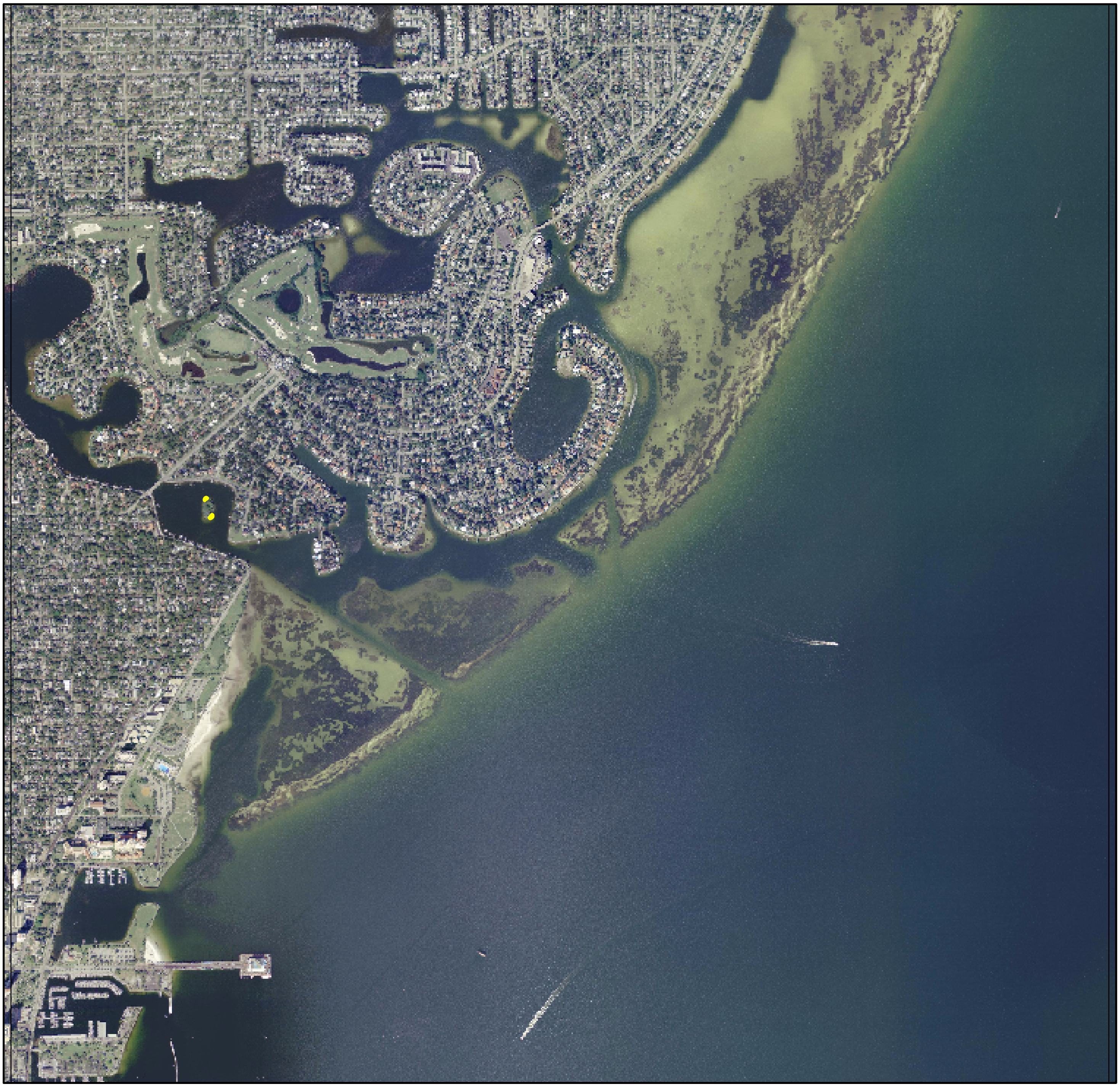
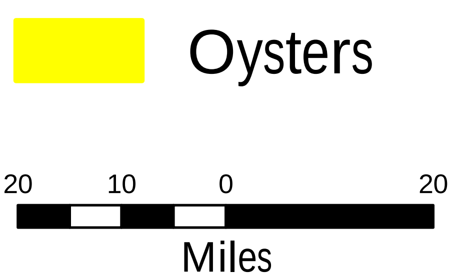
See Map 14

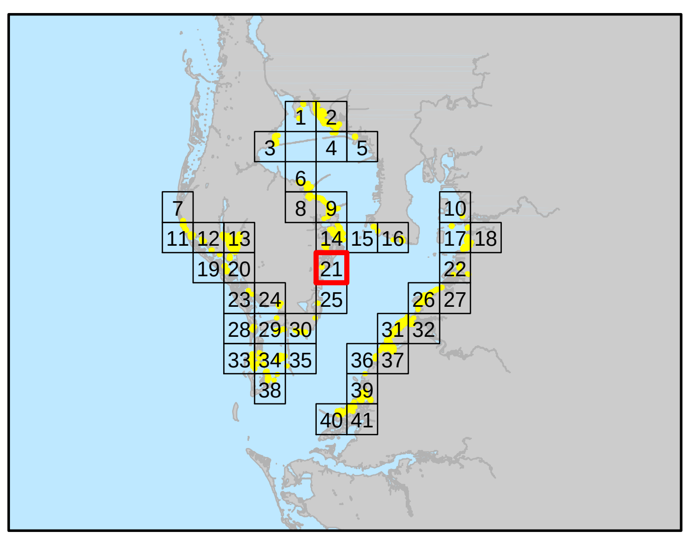


See Map 25

Tampa Bay Oyster Mapping

4





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See Map 13

See Map 19

See Map 23

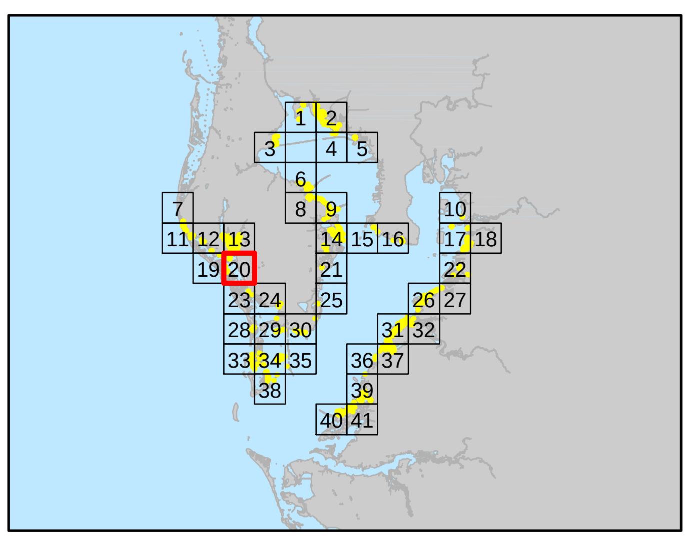
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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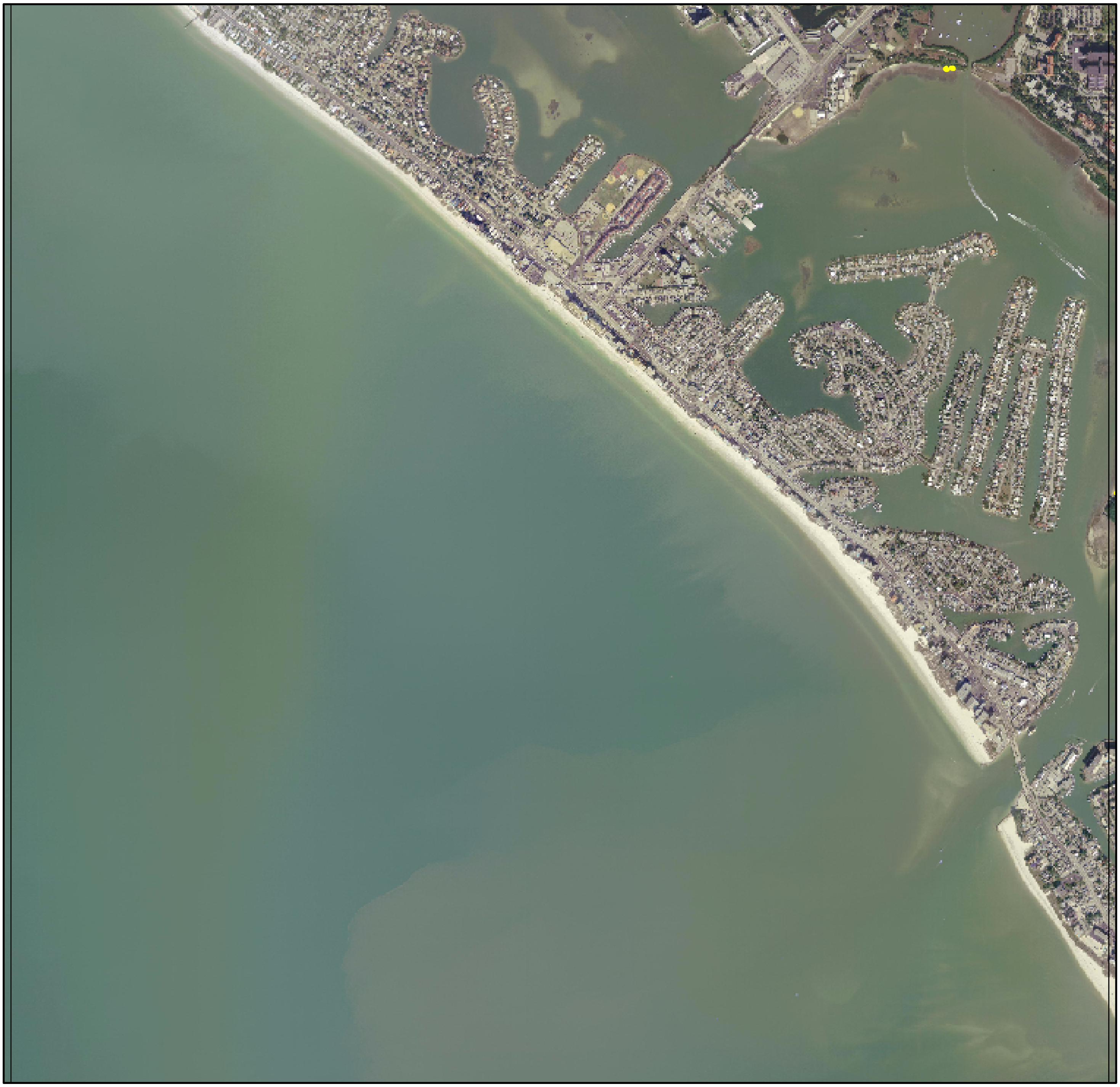
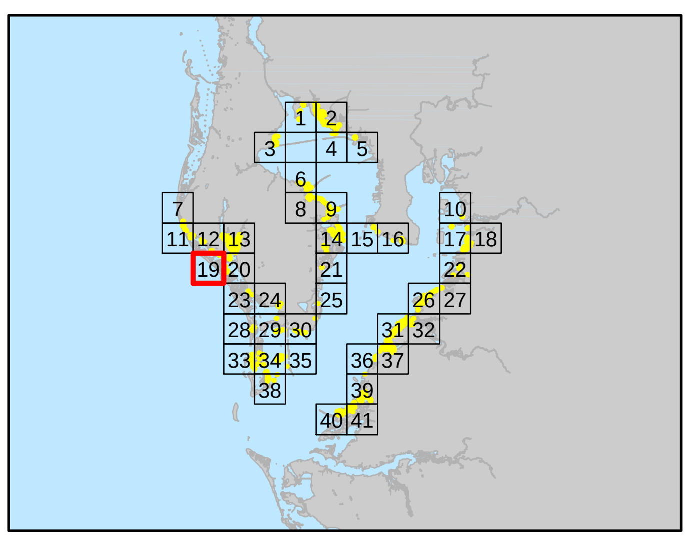


See Map 20

Tampa Bay Oyster Mapping

Oysters

4



20 10 0 20

Miles

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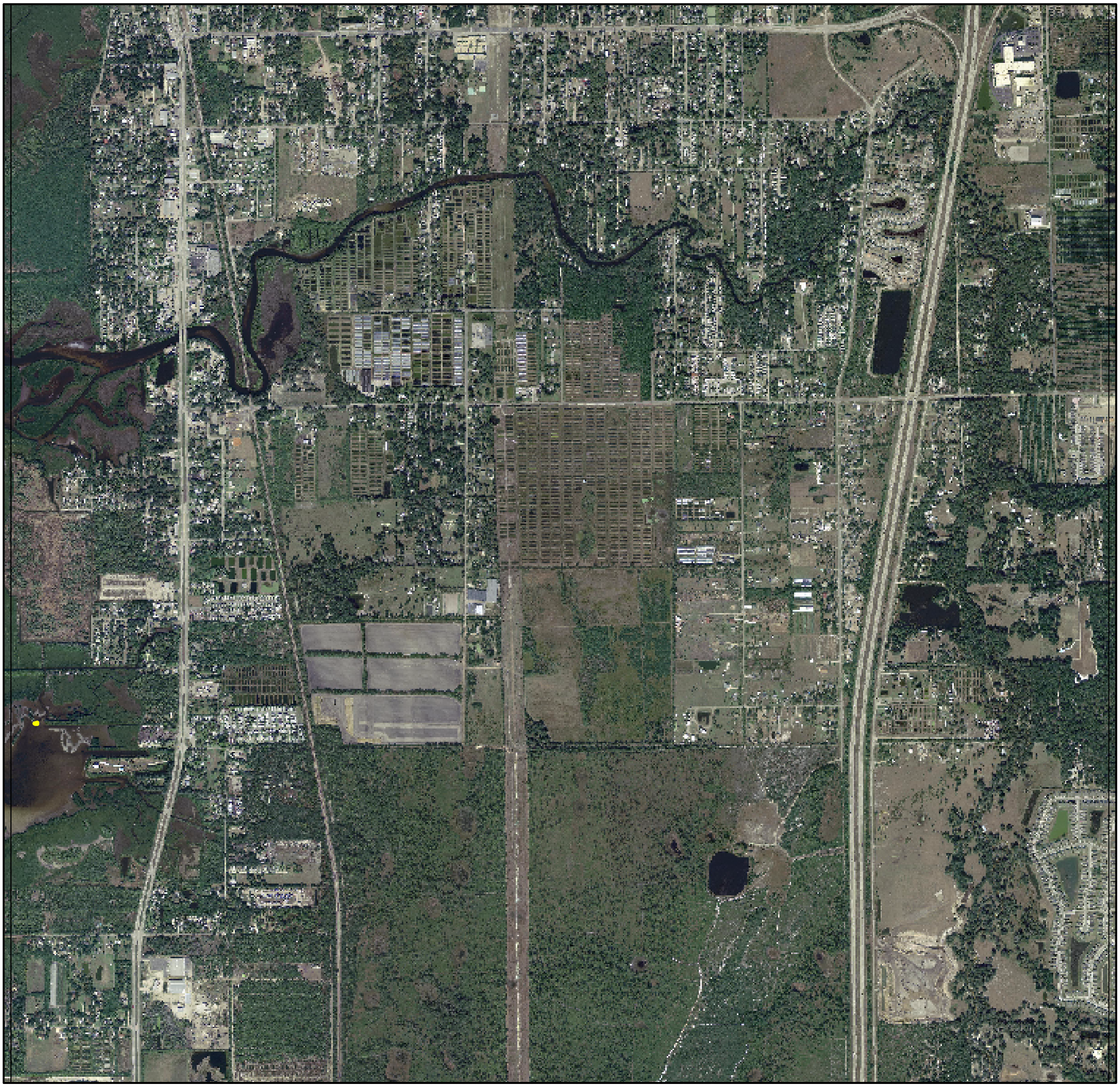
See Map 17



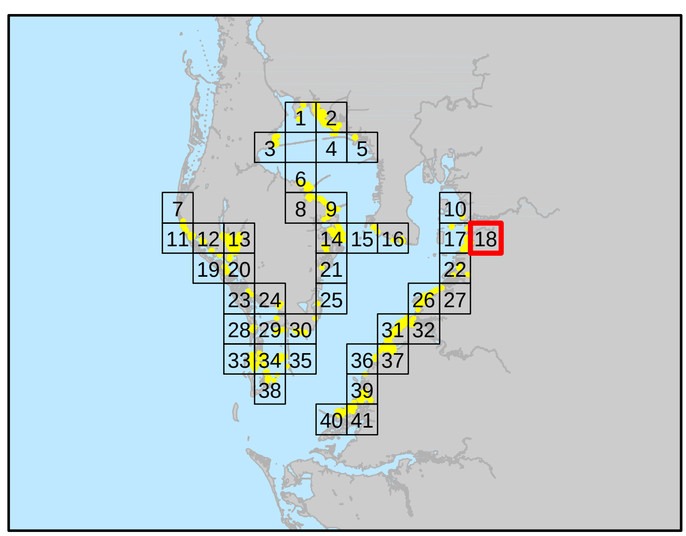
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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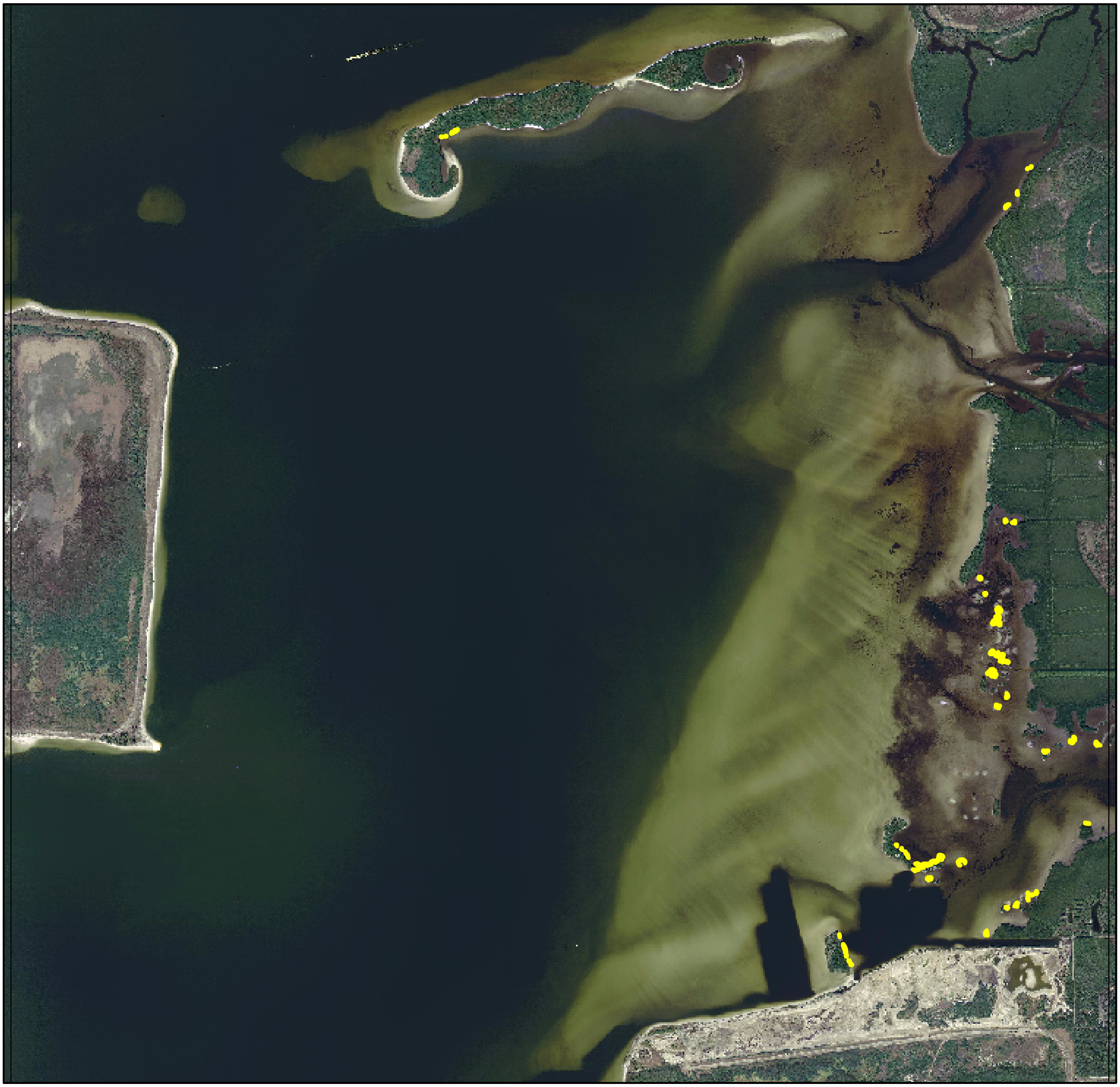
See Map 10



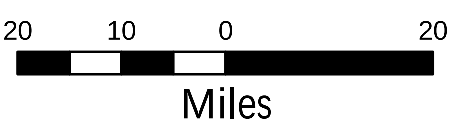
See Map 18

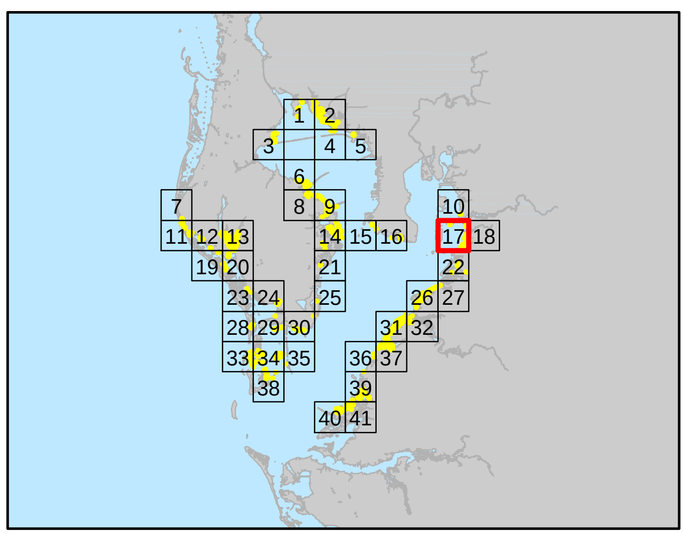
See Map 22

Tampa Bay Oyster Mapping

4

Oysters





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See Map 15

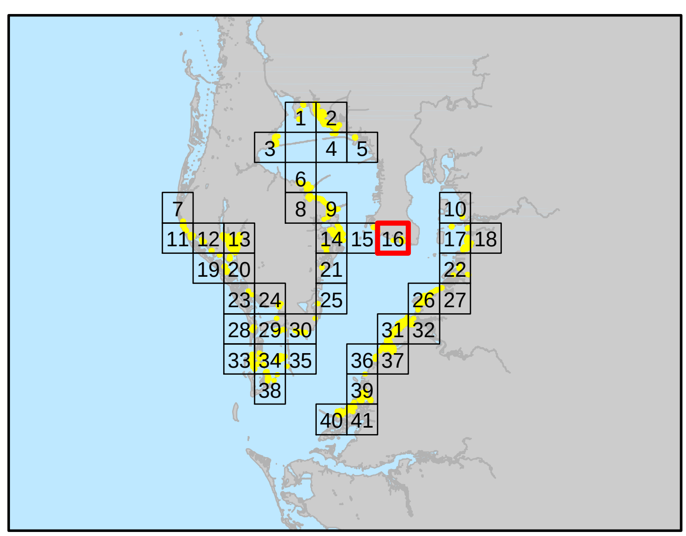
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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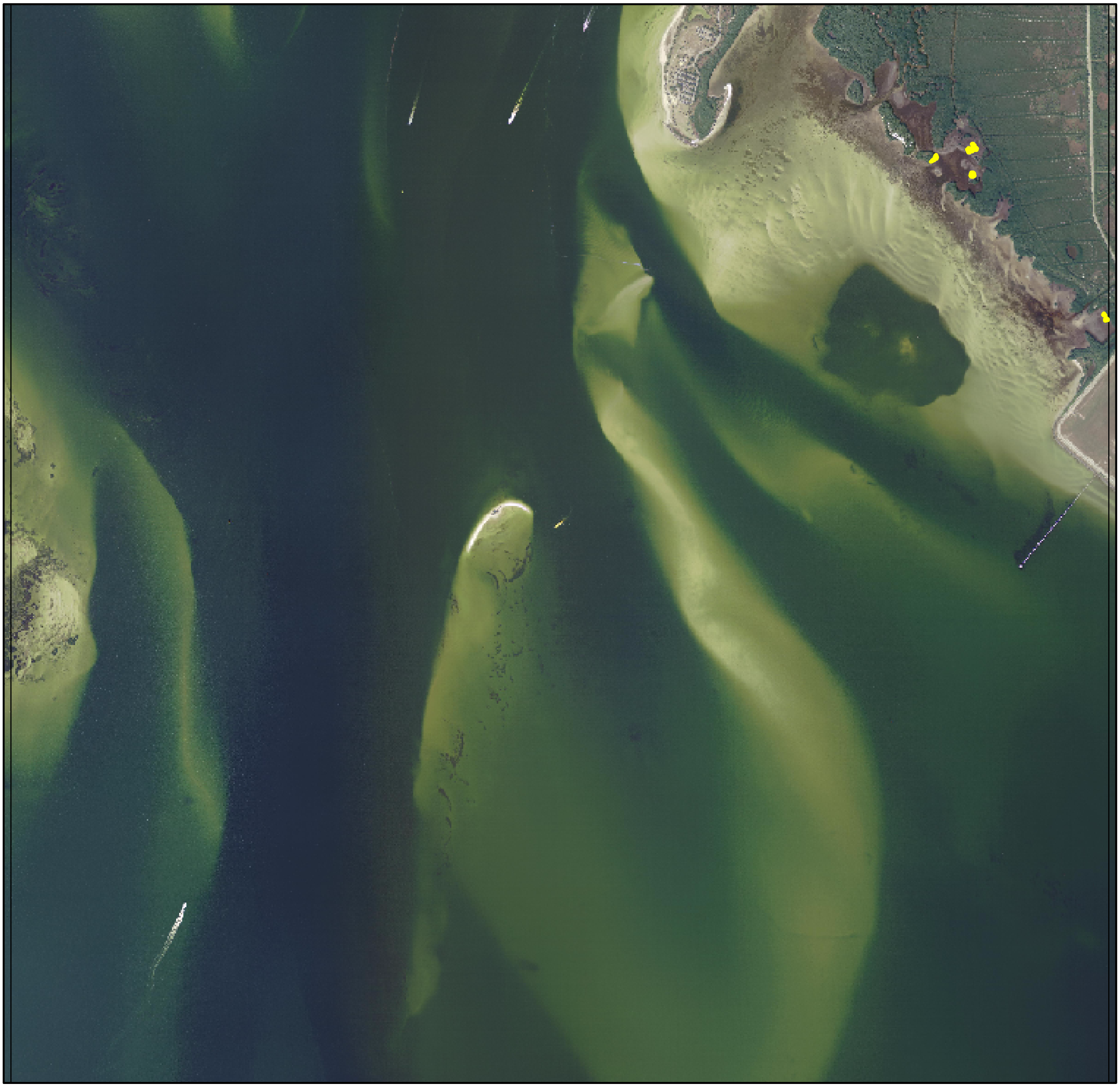


See Map 16

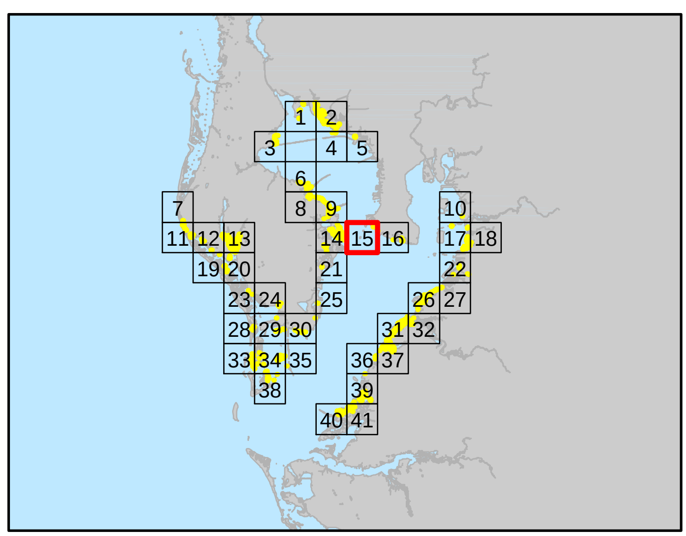
Tampa Bay Oyster Mapping

Oysters

20 10 0 20

Miles

4



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See Map 9

See Map 15

See Map 21

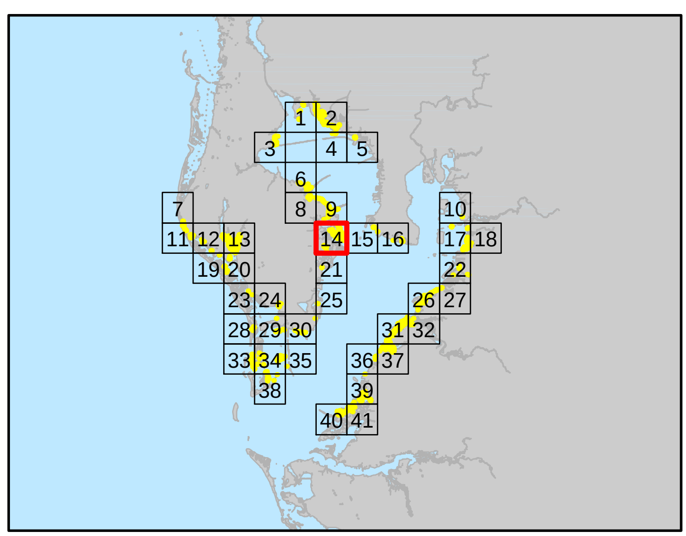
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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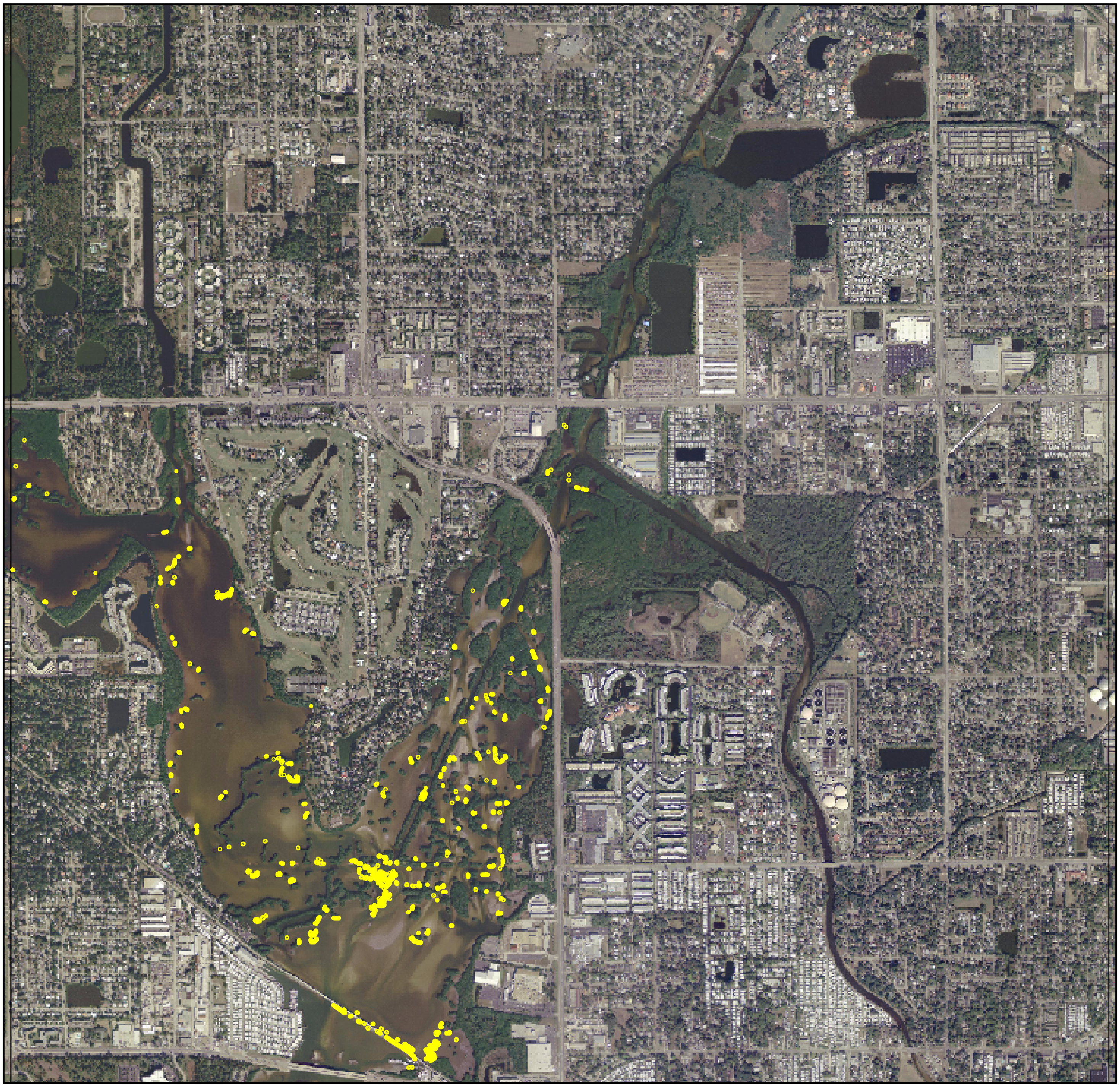
See Map 12



See Map 20

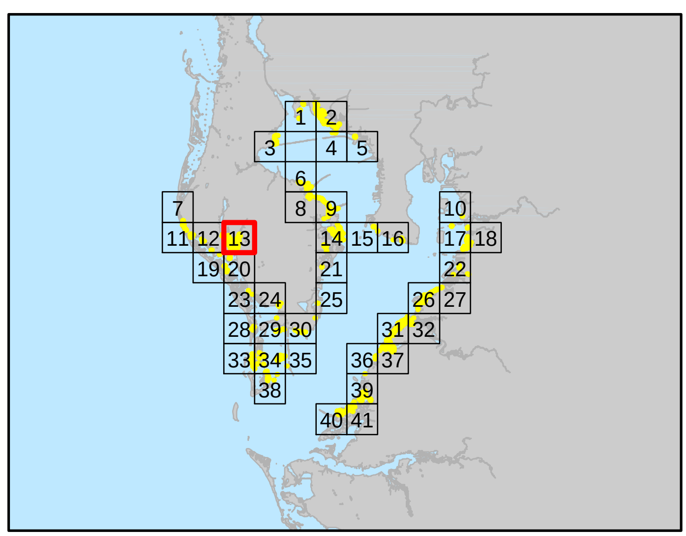
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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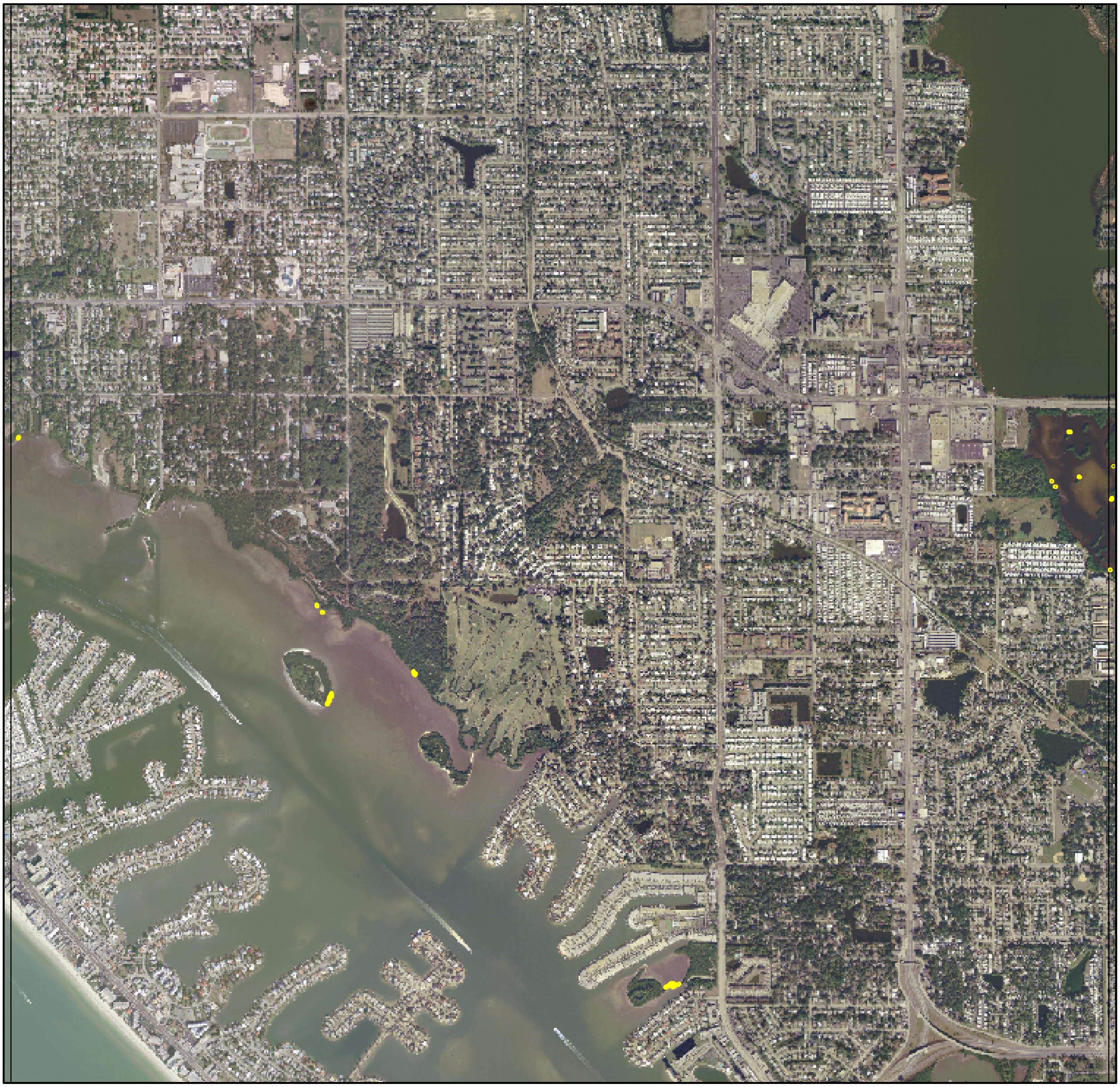


See Map 11

See Map 13

See Map 19

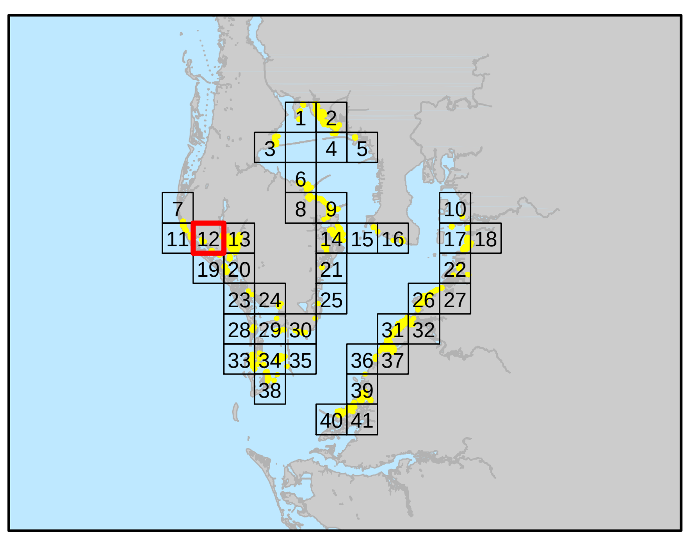
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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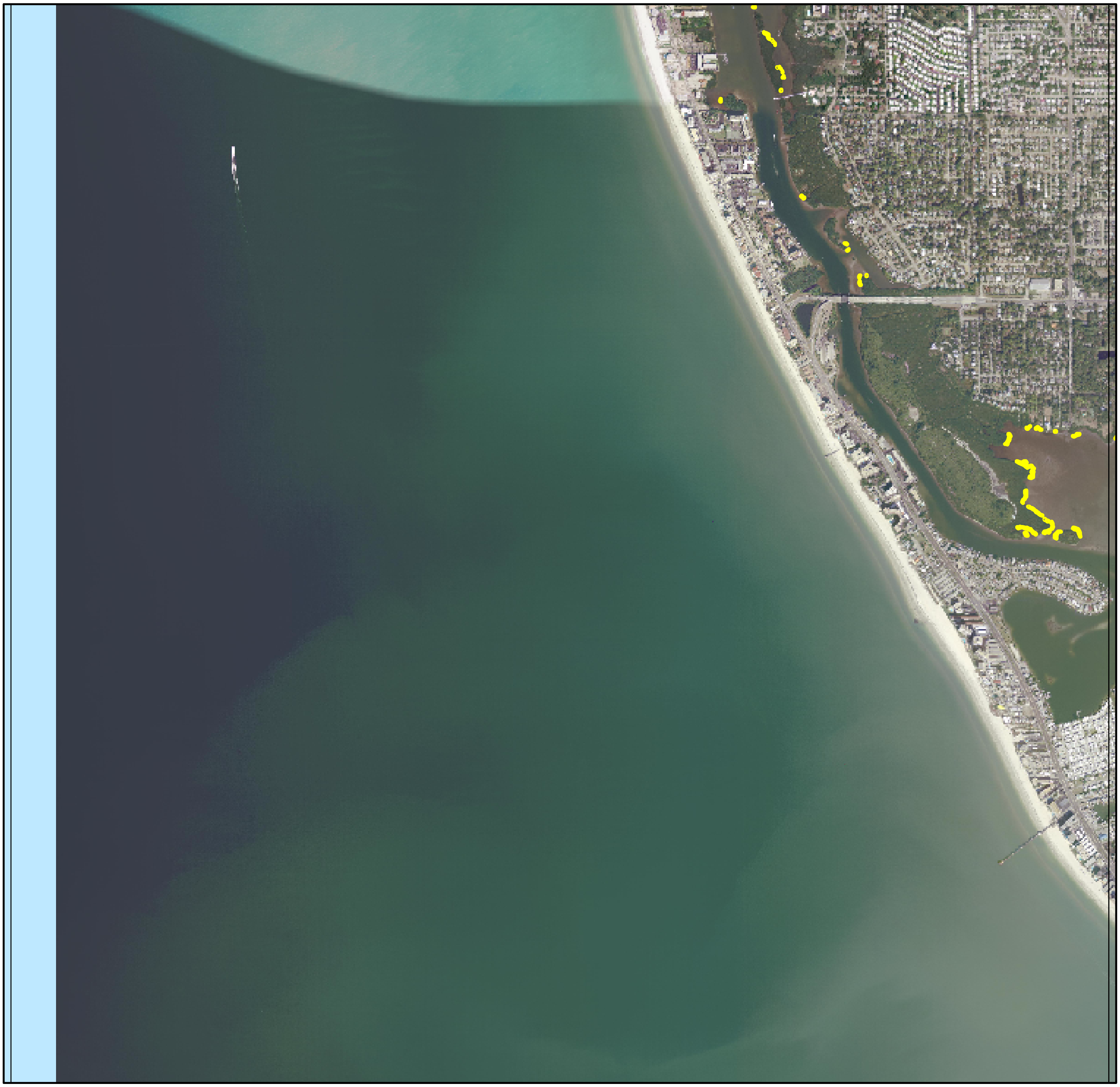


See Map 12

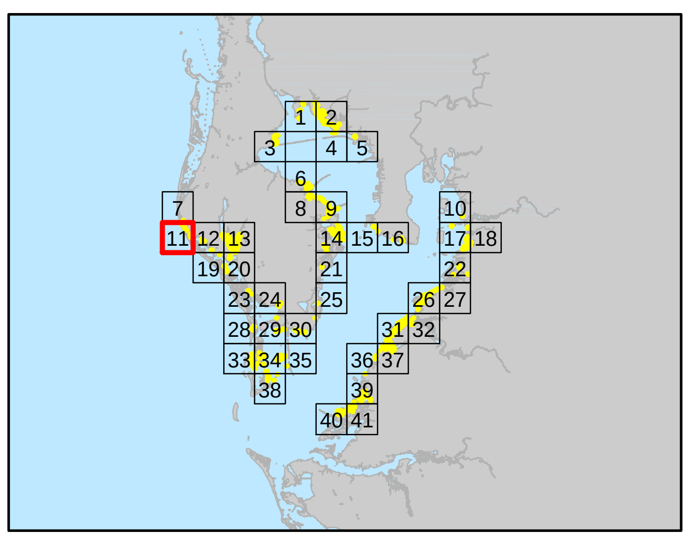
Tampa Bay Oyster Mapping

4

Oysters

20 10 0 20

Miles



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See Map 17

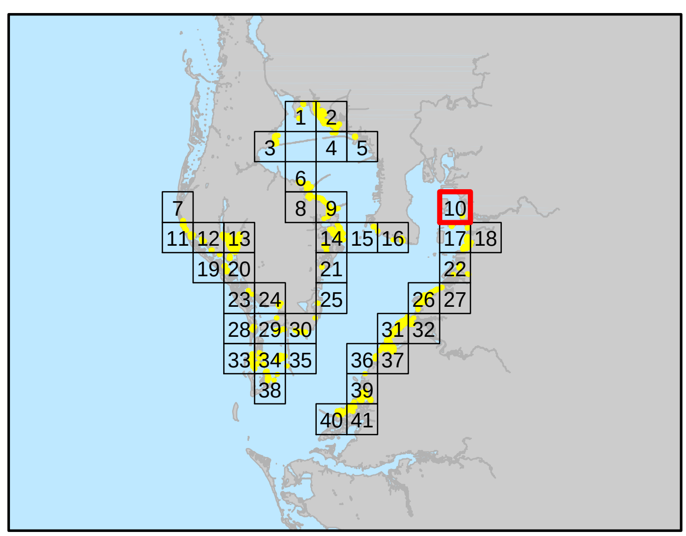
Tampa Bay Oyster Mapping

Oysters

20 10 0 20

Miles

4



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See Map 8

See Map 14

Tampa Bay Oyster Mapping

Oysters

4

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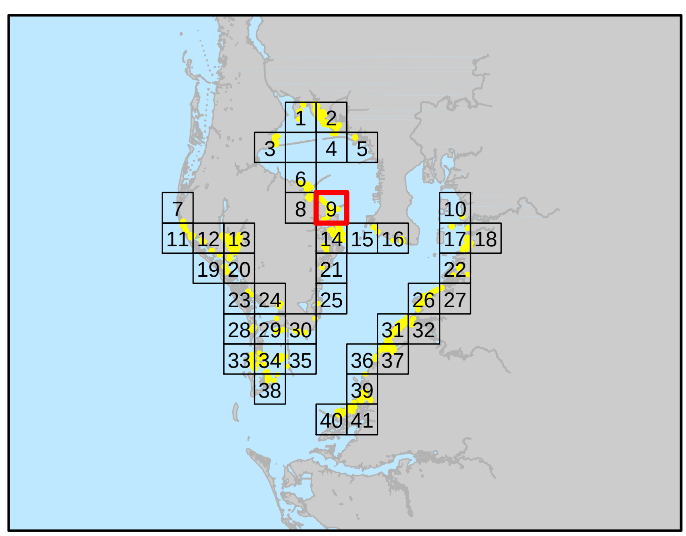
Miles



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See Map 6

See Map 9

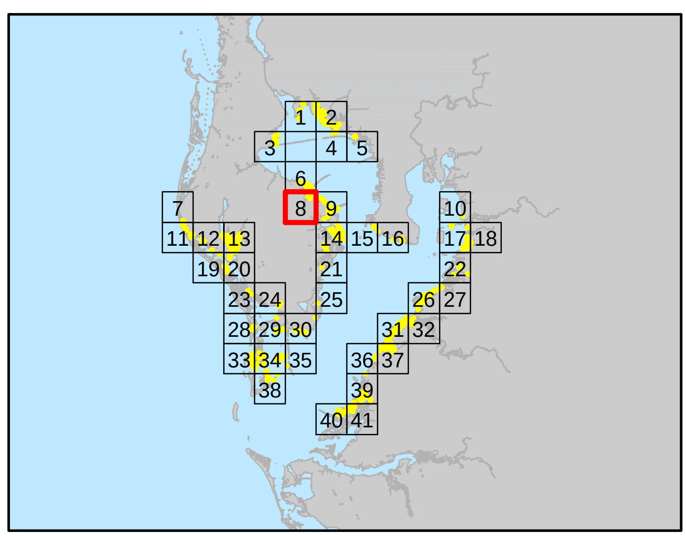
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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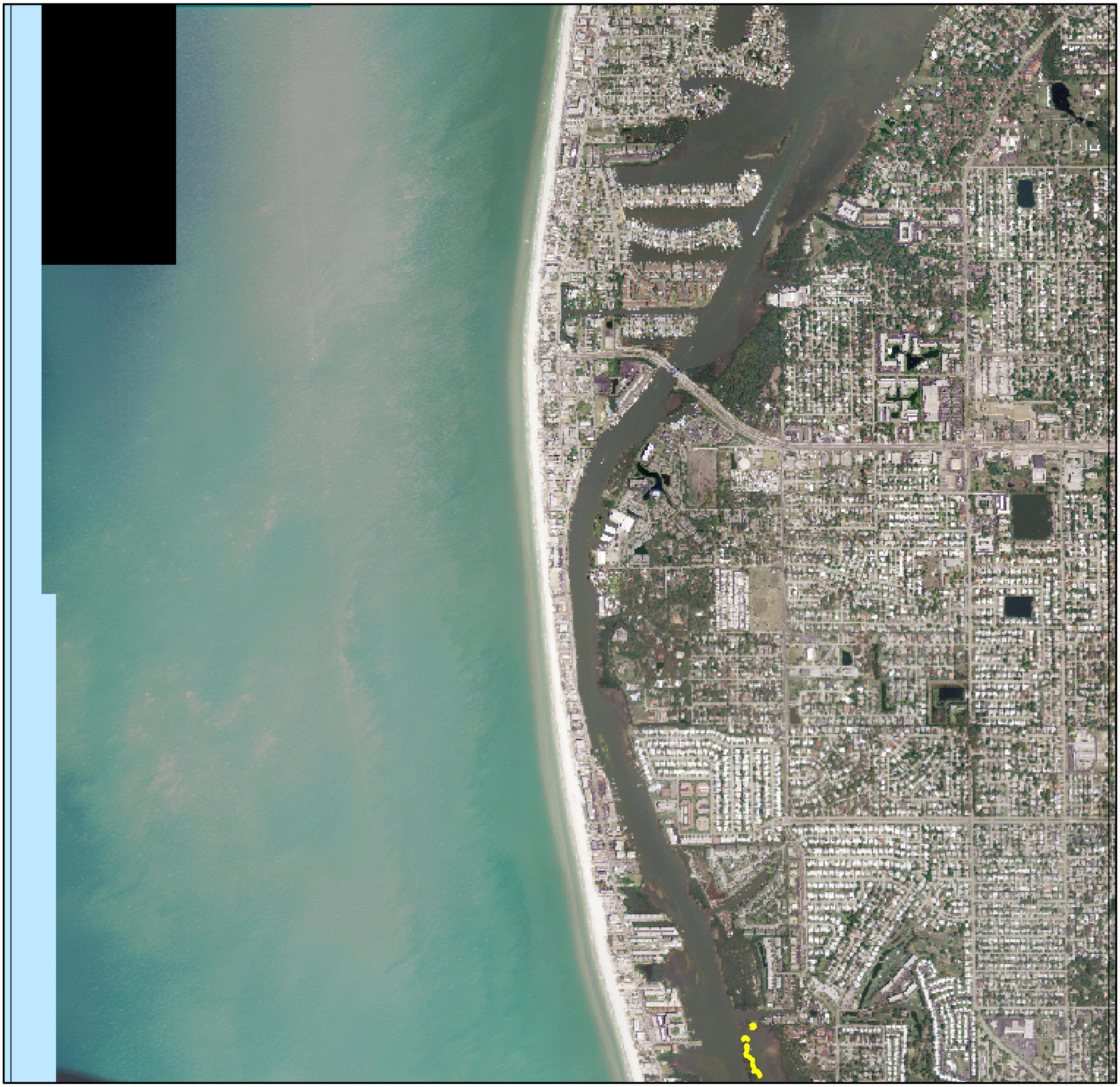

See Map 11

Tampa Bay Oyster Mapping

4

Oysters

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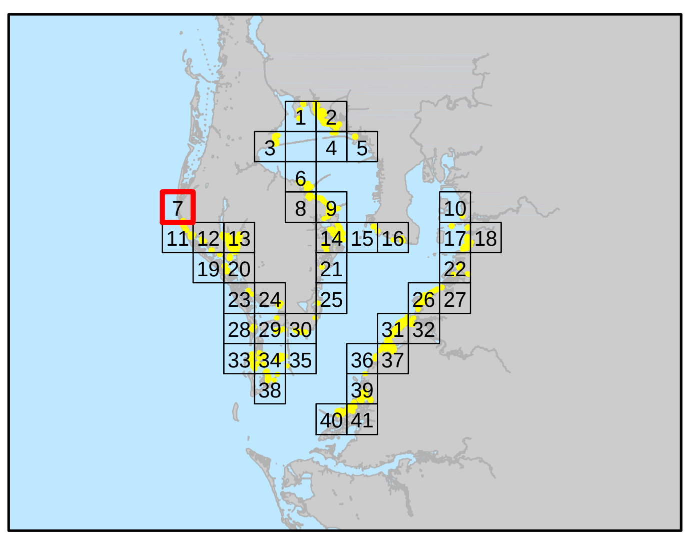
Miles



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See Map 8

Tampa Bay Oyster Mapping

Oysters

4

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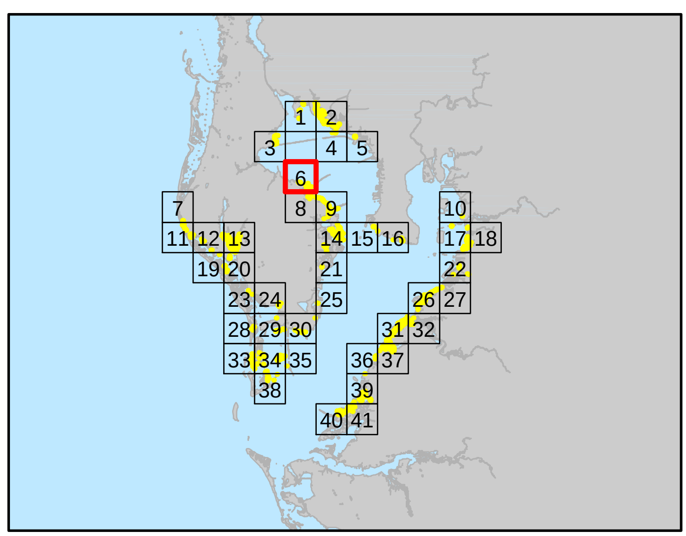
Miles



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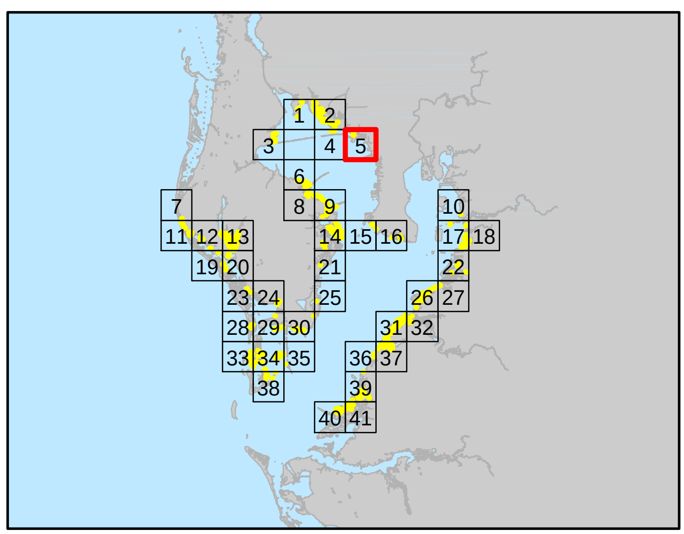
See Map 4

Tampa Bay Oyster Mapping

Oysters

4



20 10 0 20

Miles

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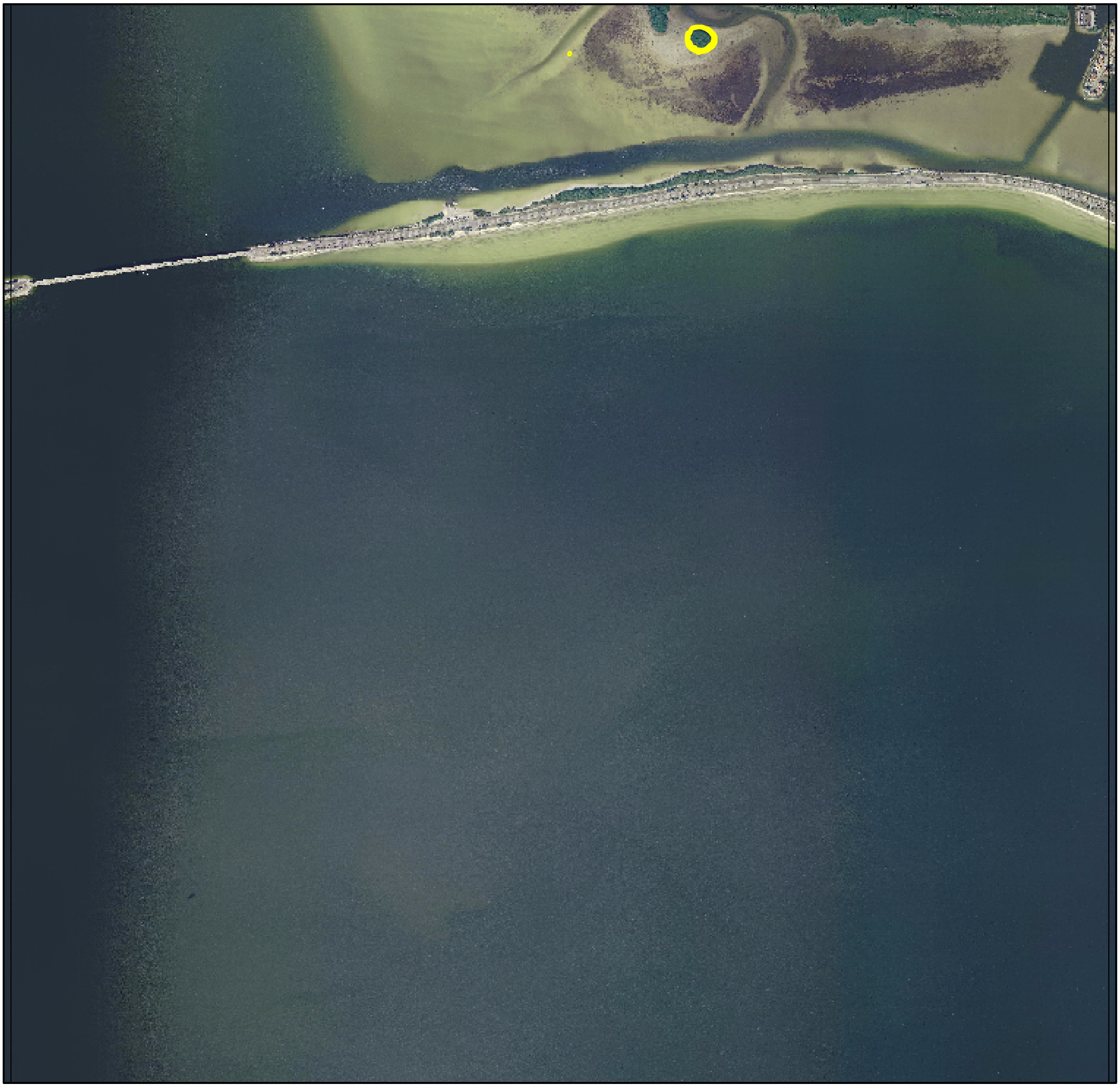
See Map 2

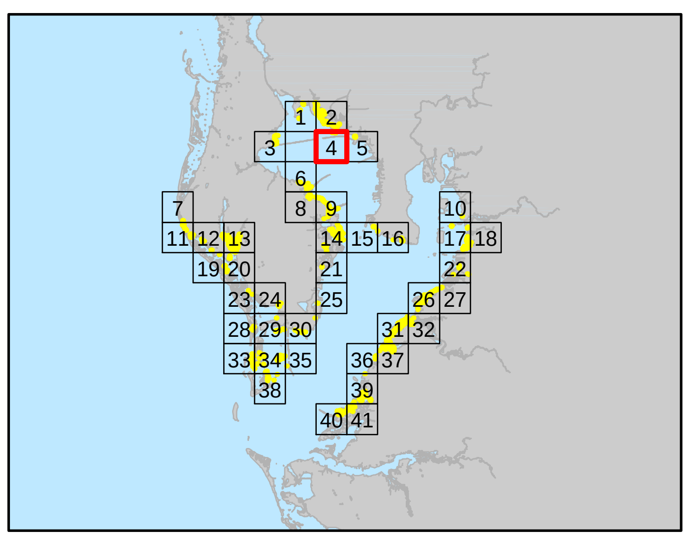


See Map 5

Tampa Bay Oyster Mapping

Oysters

4



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Miles

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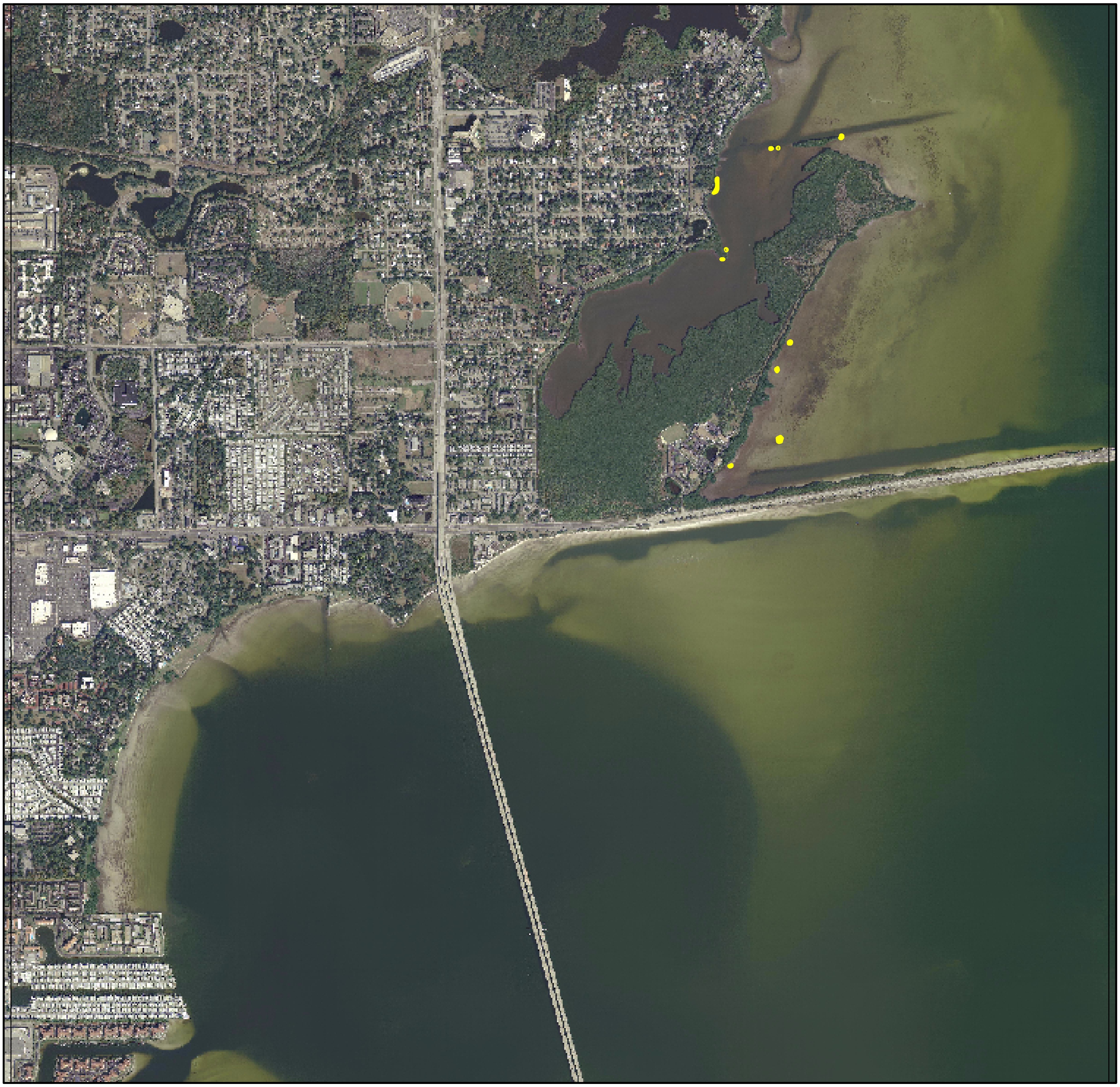

Tampa Bay Oyster Mapping

4

Oysters

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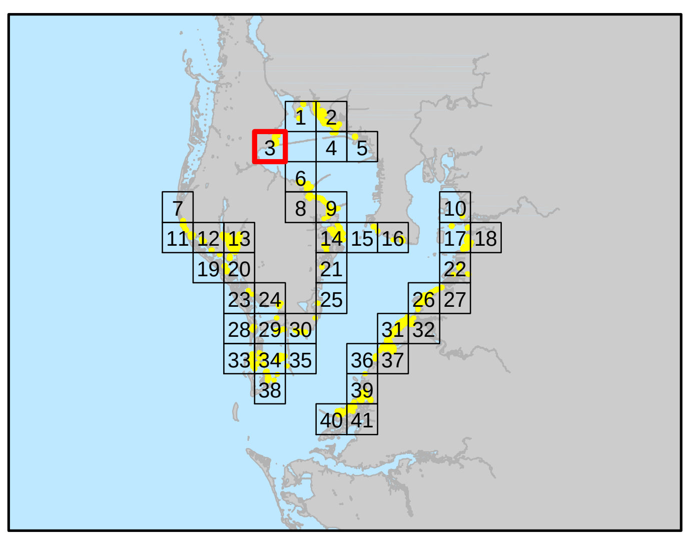
Miles



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See Map 1

See Map 4

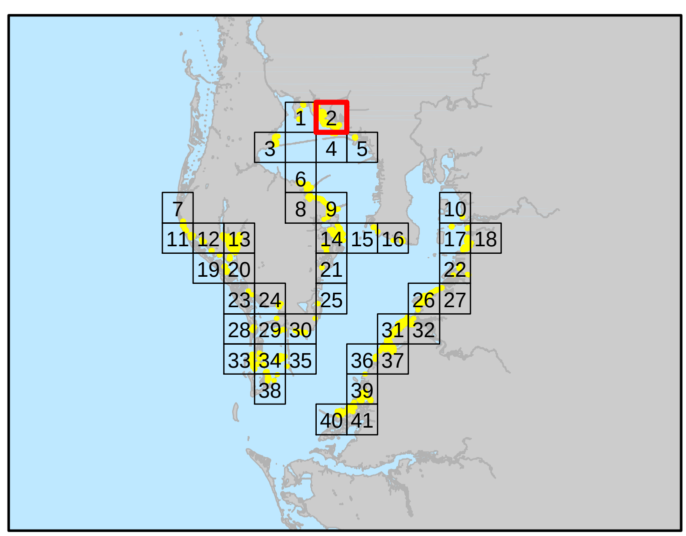
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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See Map 2

Tampa Bay Oyster Mapping

Oysters

4

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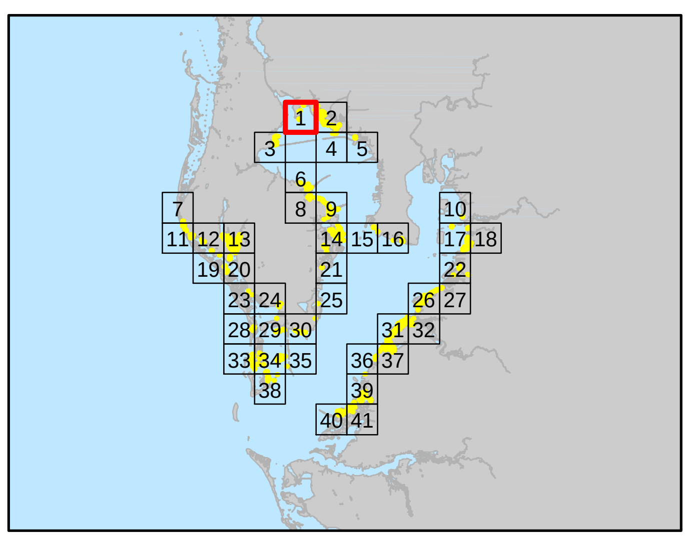
Miles



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See Map 39

See Map 40

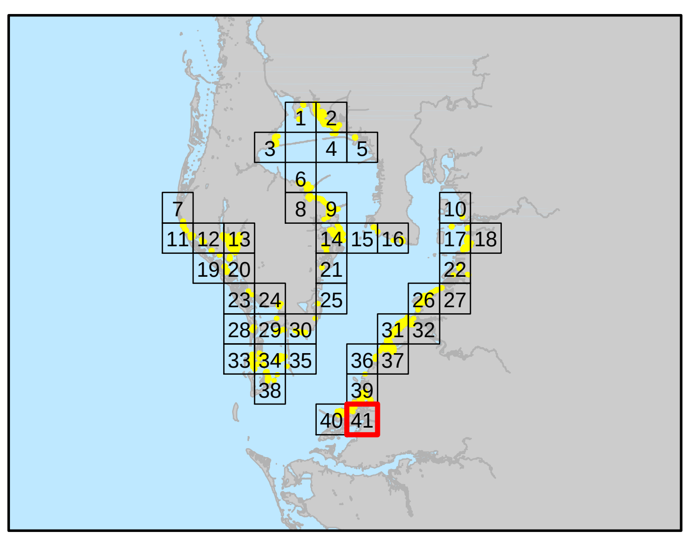
Tampa Bay Oyster Mapping

Oysters

4

20 10 0 20

Miles



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Attachment 8: Historic Maps

Nautical Charts:

1928
1930
1935
1943
1959
1969
1978
1988

T-Sheet:

1927

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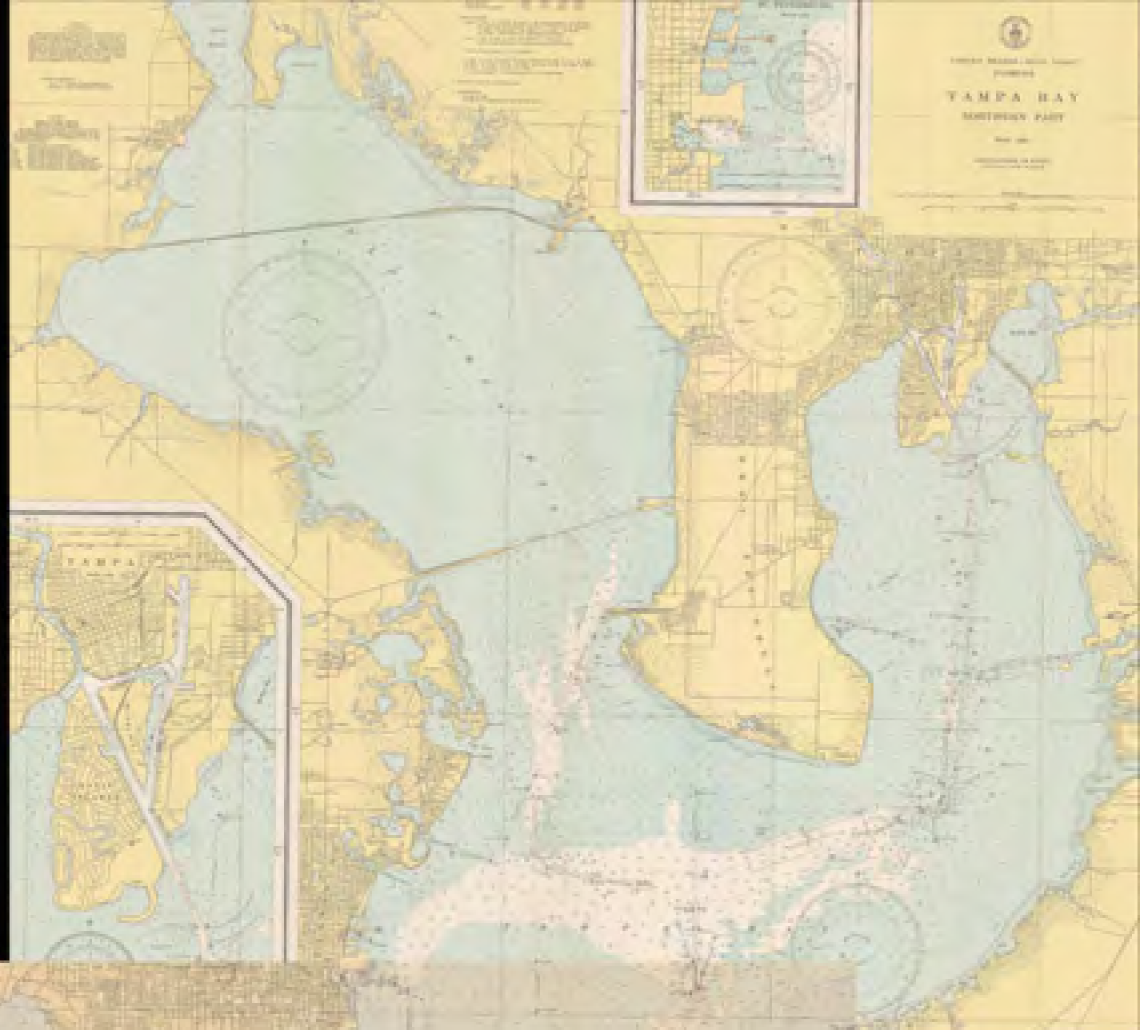

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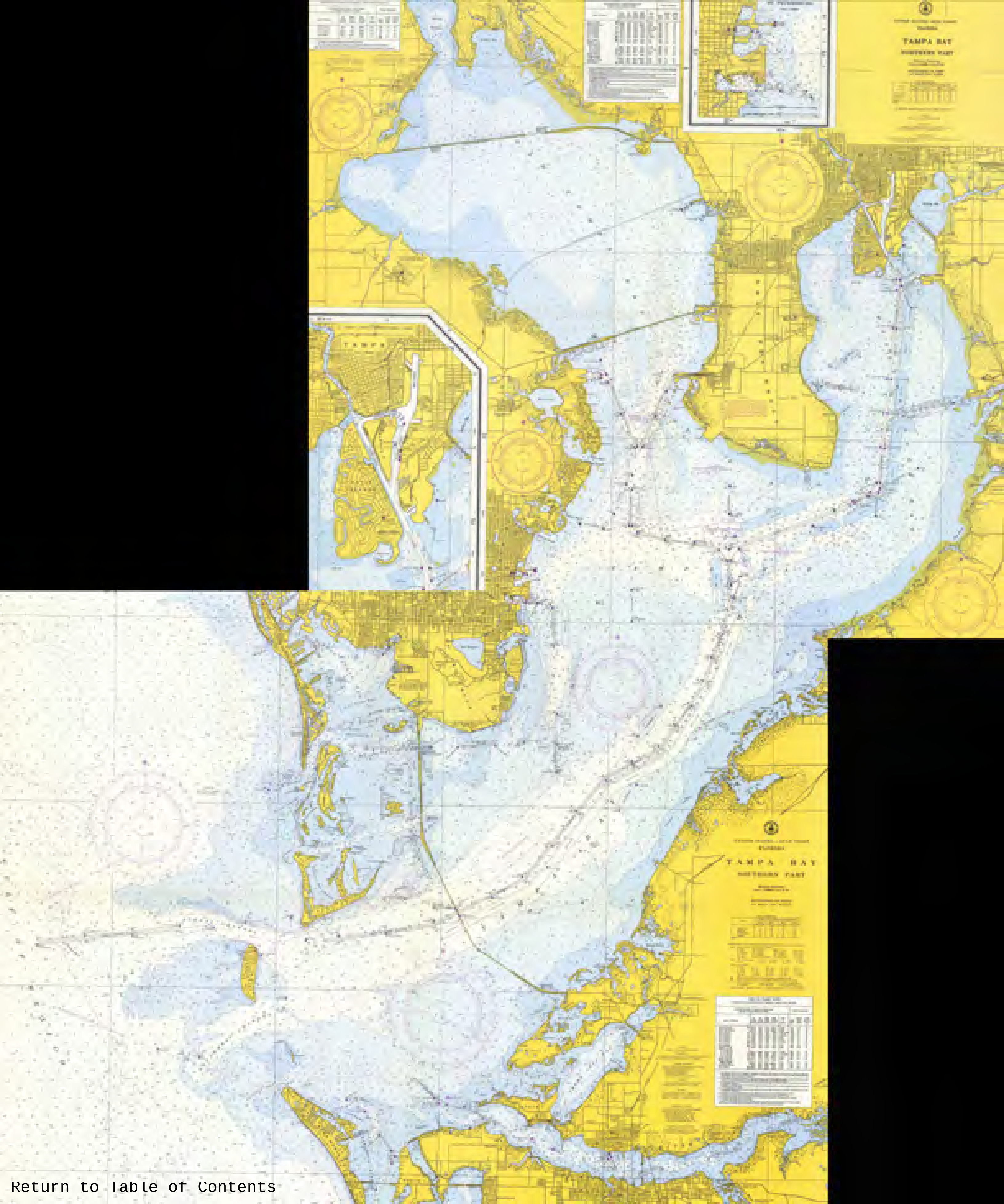

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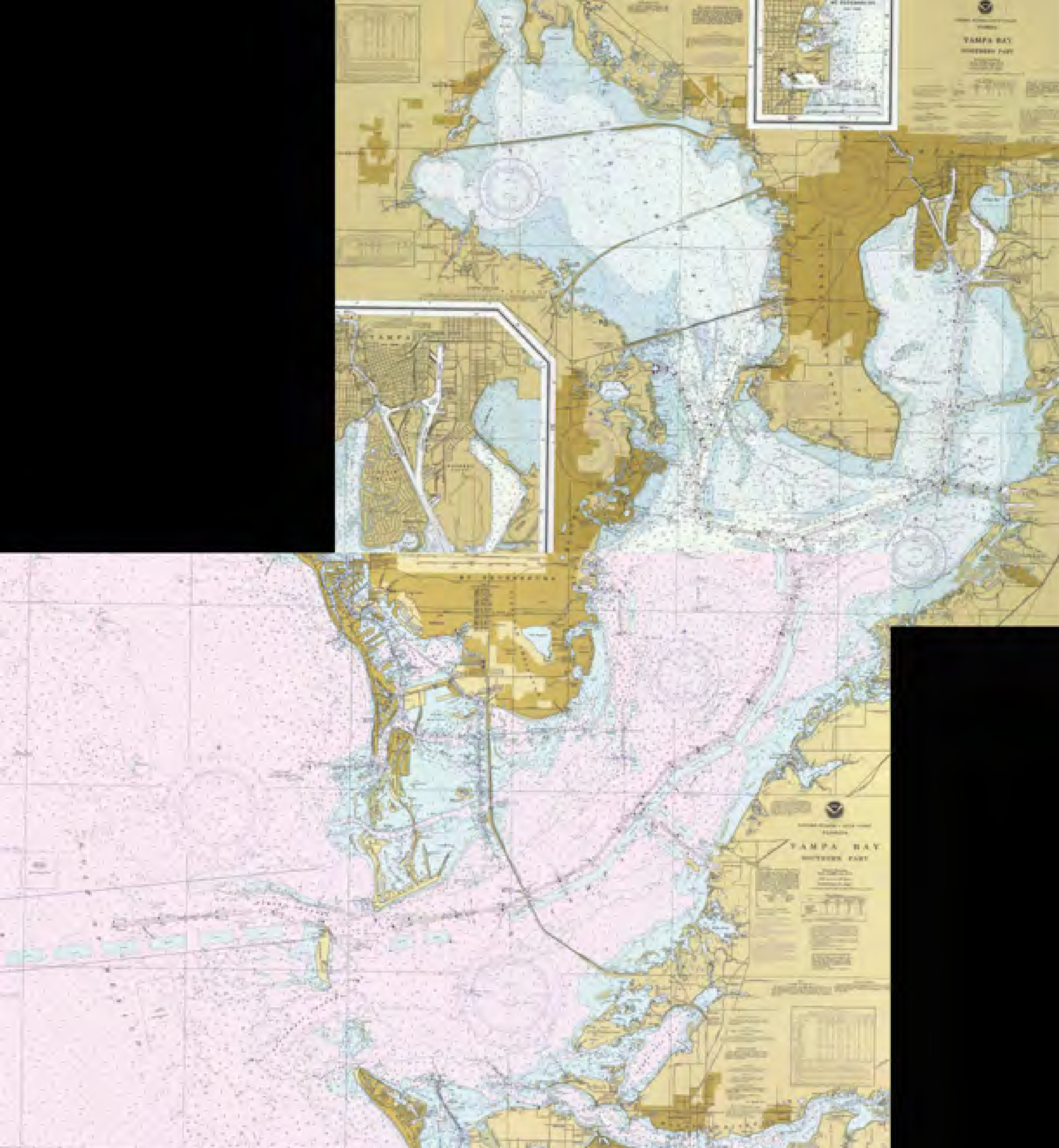

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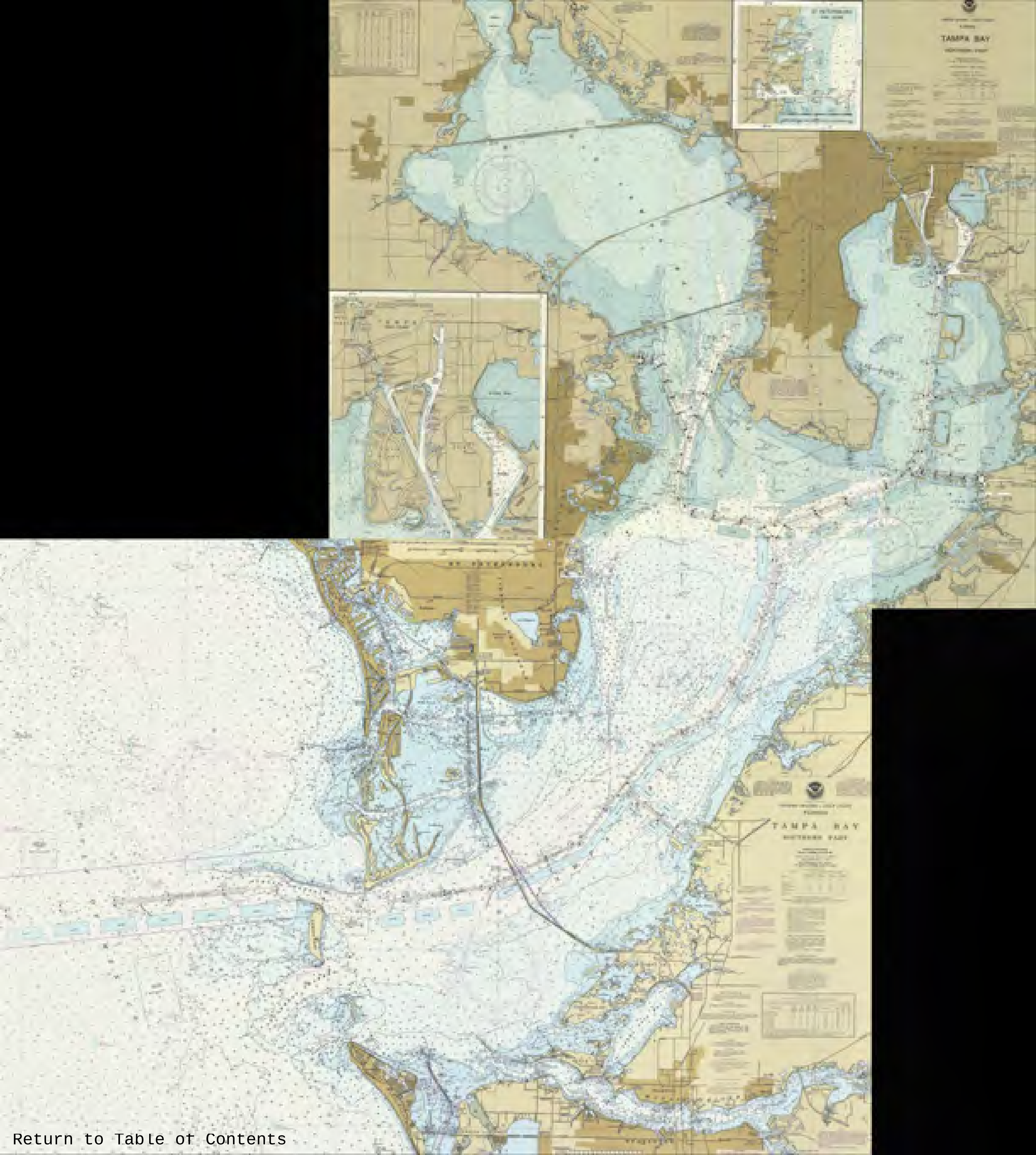

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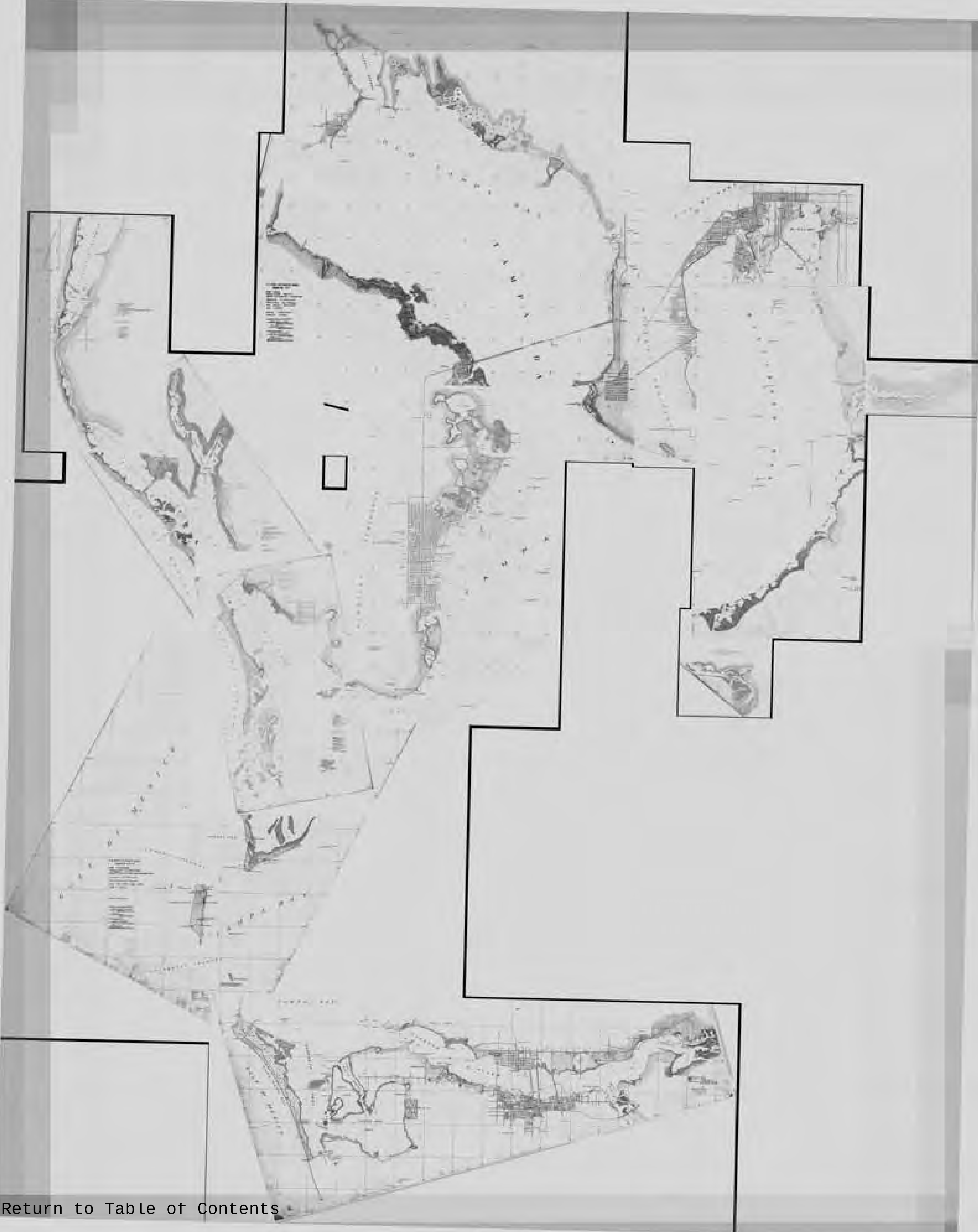

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Appendix: Associated CERP Activities

<u>Tampa Bay Survey Summary</u>

Oyster reefs in Tampa Bay are being monitored by the FWC/FWRI Molluscan Fisheries research group as part of a larger effort to evaluate the impacts of the Comprehensive Everglades Restoration Program (CERP) on oyster resources in southeast Florida. Select oyster reefs in Tampa Bay, along with select reefs in Mosquito Lagoon and the Sebastian River, are incorporated into the CERP oyster monitoring program as outlier populations, subject to many of the same large-scale forces that influence oyster reefs in southeast Florida but exempt from any direct impact of CERP activities. Reefs in the Loxahatchee River, the St. Lucie River, Lake Worth Lagoon, and Biscayne Bay are monitored for the direct impacts of CERP activities.

We sample oysters at three stations in lower Tampa Bay, including Pinellas Point, the Blackthorne Memorial, and Madelaine Key (Figure 1), and we conduct semi-annual adult density surveys at each of those stations. Density surveys consist of counting all live and dead oysters (generally > 10 mm shell height) within each of ten randomly allocated 1-m^2 quadrats at each station. Adult abundance surveys are conducted each spring and fall, but for the present study we provide results only from our most recent (Fall, 2006) Tampa Bay oyster reef sampling effort (Table 1).

The three oyster reefs that we monitor in Tampa Bay support relatively dense adult populations. Lowest mean density of live oysters was recorded at Station 3 (Madelaine Key); there we recorded approximately 186 live oysters per square meter. At the other two sites, mean adult oyster abundance exceeded 250 per square meter. In comparison, average live oyster density at our St. Lucie study site on the east coast ranges from 26 in the south fork to 200 in the central estuary. In the Loxahatchee estuary, mean adult oyster density exceeds 380 per square meter. Thus, although the oyster reefs that we monitor in Tampa Bay do not support the most dense adult populations of those we monitor, they do compare favorably to many other sites in Florida.

Our results suggest that oysters can thrive in Tampa Bay given the proper environmental (e.g. substrate) and water quality conditions. Our mapping efforts suggest that such conditions are extant in areas such as Cross Bayou and Cockroach Bay and may be extant in other areas where oyster reefs are presently in a state of decline or are altogether absent. If those sites can be identified, reef restoration may be a viable strategy for increasing the availability of habitat and ecosystem services that oyster reefs provide.

Tampa Bay – Station 1		
Quadrat	**# Live Oysters**	**# Dead Oysters**
1	278	271
2	2	34
3	388	259
4	251	116
5	105	69
6	669	360
7	242	181
8	387	666
9	140	92
10	87	402
Mean	254.90	245.00
S. D.	192.98	193.11

Tampa Bay – Station 2		
Quadrat	**# Live Oysters**	**# Dead Oysters**
1	672	185
2	418	117
3	234	61
4	617	410
5	50	8
6	166	50
7	328	40
8	449	142
9	333	398
10	375	342
Mean	364.20	175.30
S. D.	190.35	153.53

Tampa Bay – Station 3		
Quadrat	**# Live Oysters**	**# Dead Oysters**
1	95	70
2	269	167
3	90	86
4	34	101
5	115	85
6	328	283
7	748	446
8	39	49
9	38	17
10	100	56
Mean	185.60	136.00
S. D.	220.97	132.28

Table 1. Density of live and dead oysters within each of ten 1-m^2 quadrats sampled at each of three stations in Tampa Bay, Florida. Station 1 is Pinellas Point, Station 2 is the Blackthorne Memorial, and Station 3 is Madelaine Key (see Figure 1 for station locations). Survey data were collected during Fall, 2006.

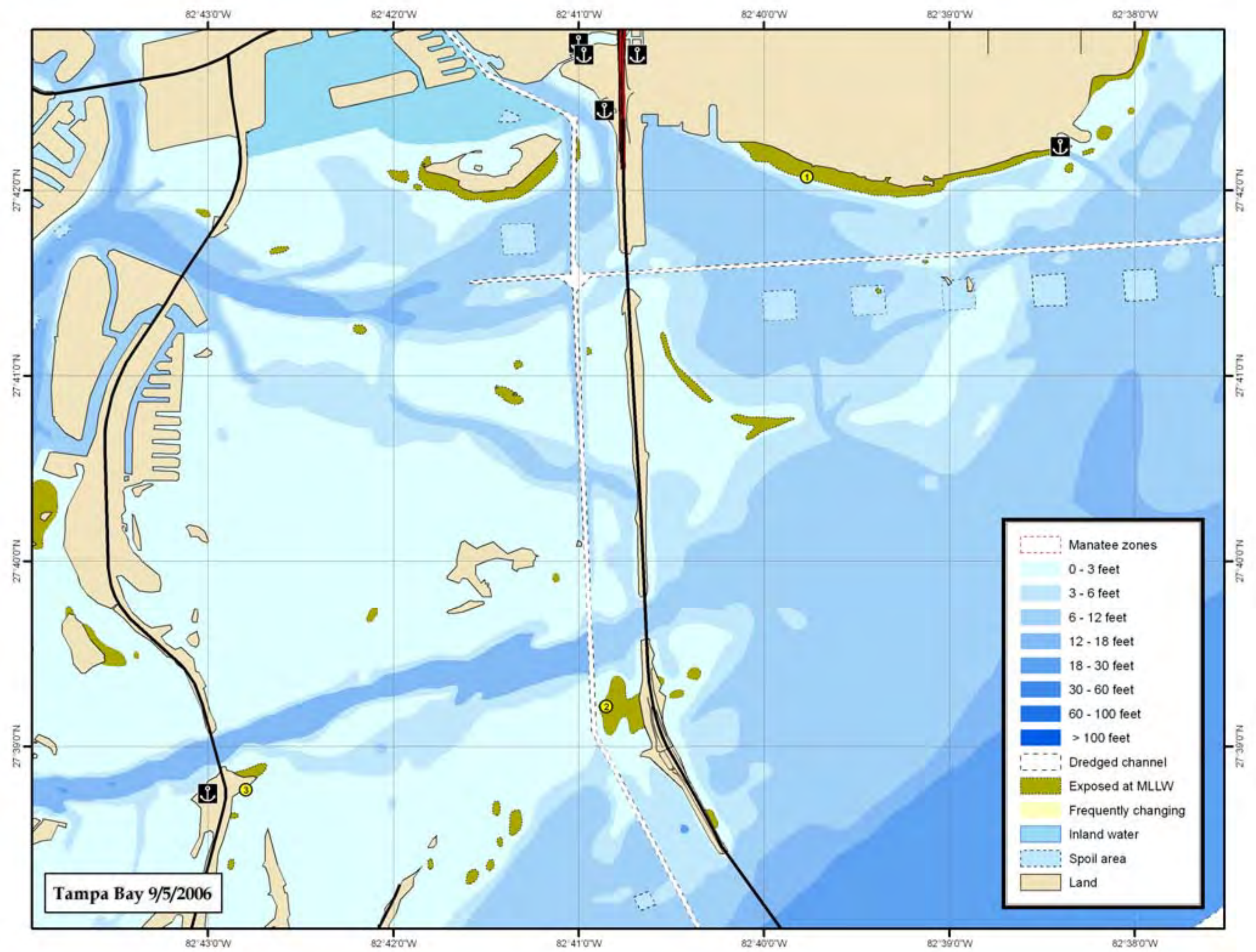

Figure 1. Station locations for adult oyster surveys conducted during Fall, 2006 in Tampa Bay, Florida. Station 1 is Pinellas Point, station 2 is the Blackthorne Memorial, and station 3 is Madelaine Key. At each station, all live and dead oysters are counted within each of ten 1-m^2 quadrats, from which mean abundance is calculated for comparison with other reefs in Tampa Bay and throughout Florida.

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