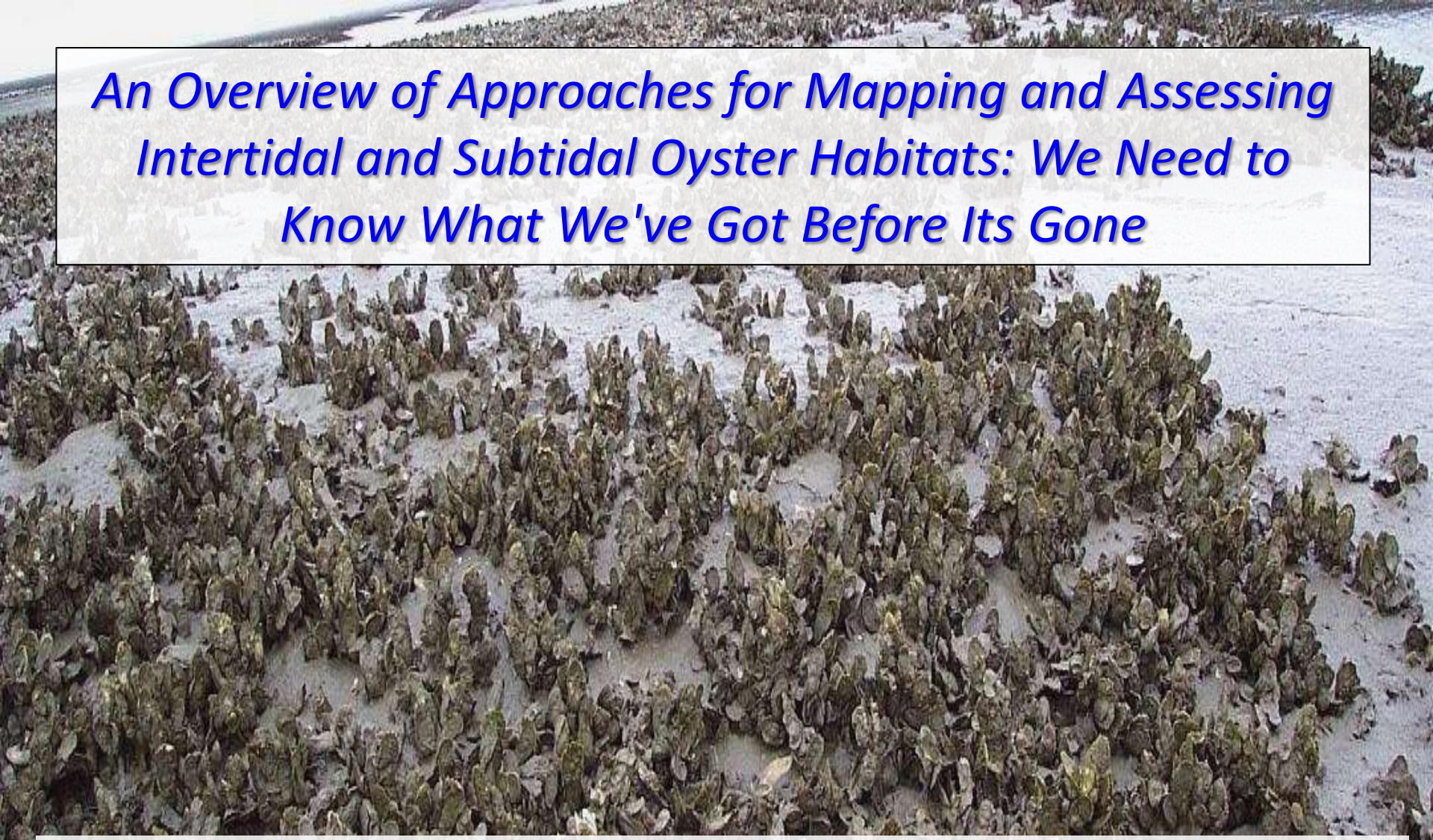
An Overview of Approaches for Mapping and Assessing Intertidal and Subtidal Oyster Habitats: We Need to Know What We've Got Before Its Gone



Loren D. Coen

OIMMP Oyster Mapping Workshop

February, 2017

FAU FLORIDA ATLANTIC UNIVERSITY

HARBOR BRANCH FLORIDA ATLANTIC UNIVERSITY

Shellfish-Focused Remote Sensing Workshop in SC, 2003

Remote Sensing of Shellfish Habitats Workshop

June 27-28, 2003: Kimbel Lodge, USC, Georgetown, South Carolina, USA

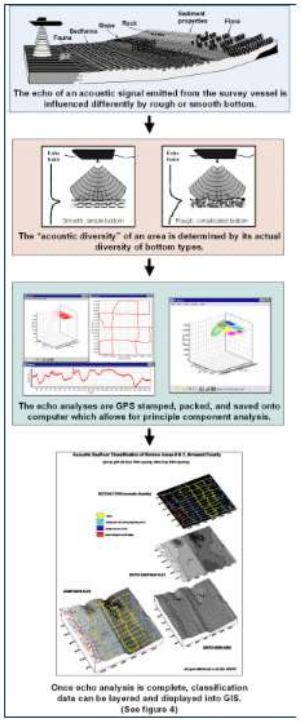
Sponsors:

ACE Basin and North Inlet-Winyah Bay National Estuarine Research Reserves, South Carolina Sea Grant Consortium, South Carolina Department of Natural Resources, Marine Resources Division, Office of Ocean and Coastal Resource Management, SCDHEC

Invited speakers provided information and generated discussions on the current state of our knowledge on remote sensing approaches, specifically those employed or considered to evaluate that status of intertidal and subtidal shellfish habitats and associated change over time in marsh-edge habitats. Speakers included researchers and managers from Florida to New Hampshire that have been working with subtidal and intertidal oyster habitats. Discussions centered on: (1) the needs of current and future mapping efforts; (2) the suitability of various remote sensing approaches; (3) software and approaches that would help automate image analysis; (4) the costs and needs to undertake larger efforts; and (5) the capabilities and cost effectiveness of employing remote sensing techniques. The presentations included general overviews of acoustic and single beam, multispectral and hyperspectral methodologies currently in use. The discussions were intended to be critical of any approach, rather a sharing of success stories, ideas and information.

Organizers (current contacts):
Dr. David Bushek, Associate Professor, Haskin Shellfish Research Laboratory, Rutgers University: Co-Organizer
Dr. Loren D. Coen, Research Professor, Department of Biological Sciences, Florida Atlantic University, Harbor Branch Campus, Lcoen1@fau.edu: Co-Organizer

» ***Download agend***



» Discussions and Questions/Interactions Among Attendees and Potential for Development of Summary Document (Grizzle, Coen, Bushek)

http://www.oyster-restoration.org/workshops-meetings-related-to-oyster-restoration/

Oyster Restoration Workgroup

Mission

In recognition of the importance of oyster reefs to overall coastal ecosystem functions, large- and small-scale restoration of oyster reef habitats is ongoing in most coastal →

Oyster Restoration News

- First phase of salt marsh restoration completed - The Independent
- If you believe in healthy coastal ecosystems, then you like oysters - Long Beach Press Telegram
- Why the Olympia Oyster Is Primed for a Comeback - Eater

Join the Oyster Restoration Workgroup

By joining the Oyster Restoration Workgroup we hope that your participation will help to increase professional contacts, facilitate interactions among disciplinary (e.g., municipal planners and research scientists) and geographically disparate groups, and ultimately develop new or unique networks of individuals interested in oyster reef restoration and related topics.

"Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico (2016)" Now Available As Preprint

Recent and Upcoming Events & Conferences

27 Jun — **World Aquaculture 2017**
World Aquaculture 2017 meeting to be held in Cape Town, South Africa on Jun. 27-30

12 Apr — **46th BEM 2017**
The 46th Benthic Ecology Meeting will take place with the SEERS Spring Meeting 2017 on April 12-16, 2017 in Myrtle Beach, SC

26 Mar — **NSA 2017 Meeting**
109th National Shellfisheries Annual Meeting, Mar. 26 – 30, 2017, in Knoxville, Tennessee, USA

23 Feb — **Oyster Integrated Mapping and Monitoring Program**

Shellfish-Focused Remote Sensing Literature

See http://www.oyster-restoration.org/oyster-restoration-research-reports/

Development of an Automated Mapping Technique for Monitoring and Managing Shellfish Distributions

A final report submitted to the NOAA-UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).

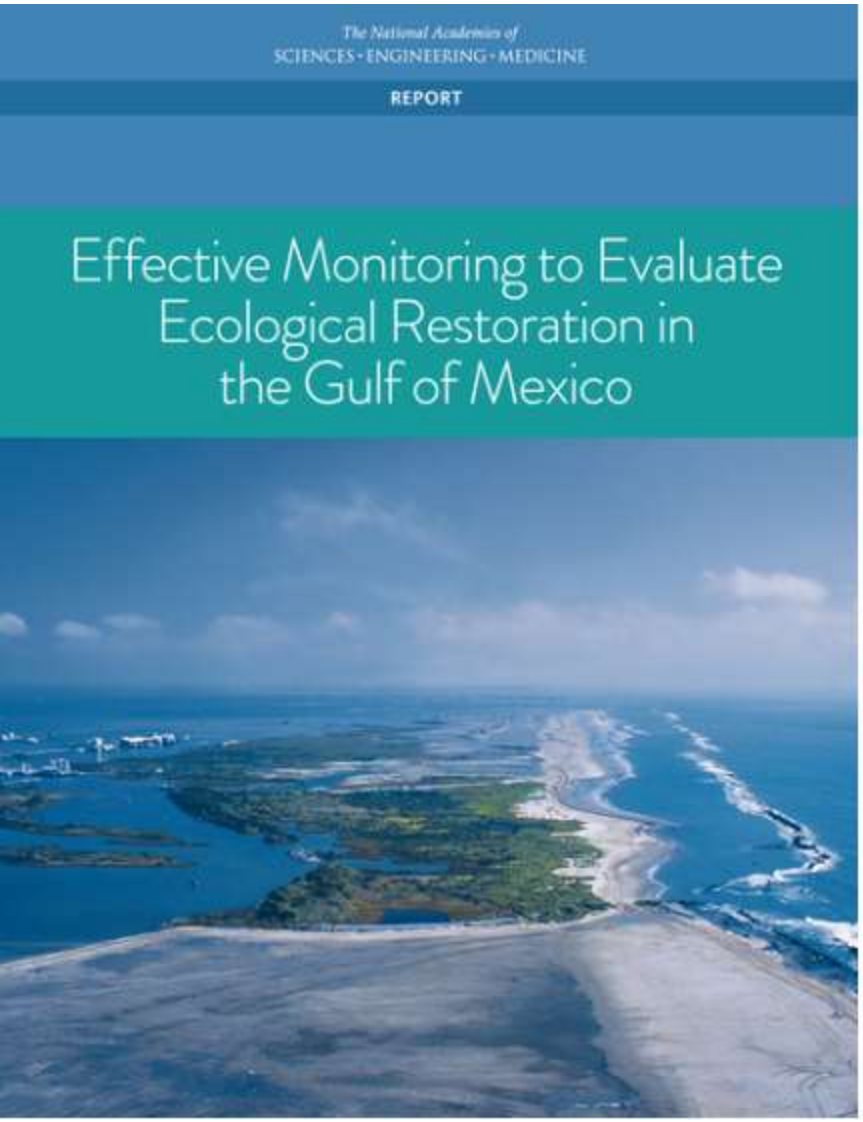
Keywords: Remote sensing, Shellfish mapping, Resource management, Mixture Tuned Matched Filtering (MTMF), Automated Feature Extraction, Classification and Regression Tree Analysis, Hyperspectral, LiDAR

> ***Download document (PDF)***

Newer Remote Sensing Work Related to Shellfish Habitats

- Allen, Y.C., C.A. Wilson, H.H. Roberts, and J. Supan, 2005. High resolution mapping and classification of oyster habitats in nearshore Louisiana using sidescan sonar. Estuaries 28:435-446.
- Anderson, D. W., and Yianopoulos, G. M, 2001. Using GIS, GPS and Digital Photography in Shellfish Management. Proceedings of the 2nd Biennial Coastal GeoTools Conference, Charleston, SC, January 8-11.
- Bolté, D., 2011. Mapping Oyster Reef Habitats in Mobile Bay NASA USRP- Internship Final Report, Marshall Space Flight Center, 1 February 16, 2011, 12pp. (pdf)
- Borrelli, M., A. Frankic, C. Felix, and J. Wilson, 2012. Using High Frequency Sidescan Sonar to Map Shellfish Habitat and Estimate Populations on a Managed Oyster Reef: Preliminary Results pdf
- Boswell, J.G. J.A. Ott, and A. Birch, 2012, Charlotte Harbor National Estuary Program Oyster Habitat Restoration Plan, Charlotte Harbor National Estuary Program, Technical Report, December 2012, 169pp plus appendices. pdf (file size: 100MB)
- Boswell, K.M., M.P. Wilson, and C.A. Wilson, 2007. Hydroacoustics as a tool for assessing fish biomass and size distribution associated with discrete shallow water estuarine habitats in Louisiana. Estuaries and Coasts 30: 607-617.
- Chauvaud, S., C. Bouchon, and R. Maniere, 1998. Remote sensing techniques adapted to high resolution mapping of tropical coastal marine ecosystems (coral reefs, seagrass beds and mangrove). International Journal of Remote Sensing 19(18):3625-3639.
- Coen, L. D., and A. Fischer, 2002. Managing the future if South Carolina's oysters: an experimental approach to evaluating current harvesting practices and boat wake impacts. Journal of Shellfish Research 21:894.
- Cracknell, A.P., 1999. Remote sensing techniques in estuaries and coastal zones – an update. International Journal of Remote Sensing 19:485-496.
- Eggleston, D.B., Ballance, E., 2007. Oyster mapping and metapopulation dynamics in Pamlico Sound, Final Report for FRG Project 06-EP-03, pp. 20. pdf
- Finkbeiner, M., W. Stevenson, W. Anderson, M. Yianopoulos, L. Coen, G. Martin, K. Cullen, 2003. Managing and monitoring intertidal oyster reefs with remote sensing in coastal South Carolina. ICSR'02, Charleston, SC. J. Shellfish. Res. 22
- Gambordella, M., L. McEachron, C. Beals, and W. S. Arnold, 2007. Establishing baselines for monitoring the response of oysters in southeast Florida to changes in freshwater input pdf [133 MB], Final Report, 176p.
- Goodwin, L.K., 2007. Evaluating the impacts of environmental parameters on shoreline erosion and related aspects: assessing the current status of vegetation, sediments, and biota. M.S. Thesis, College of Charleston, SC, 117pp. pdf
- Goshimam, S. and H. Fujiwara, 1994. Distribution and abundance of cultured scallop Placopecten yessionsis in extensive sea beds as assessed by underwater camera. Mar. Ecol. Prog. Ser. 110:151-158.
- Grizzle, R.E., Adams, J.R., and L.J. Walters, 2002. Historical changes in intertidal oyster (*Crassostrea virginica*) reefs in a Florida lagoon potentially related to boating activities. J. Shellfish Res. 21:749-756.
- Grizzle, R.E., L.G. Ward, R. Langan, G.M. Schnaittacher, J.A. Dijkstra, and J.R. Adams. 2003. Environmental monitoring at an open ocean aquaculture site in the Gulf of Maine: results for 1997-2000. In: Open Ocean Aquaculture: from Research to Reality. Eds.: C.J. Bridger and B.A. Costa-Pierce. The World Aquaculture Society, Baton Rouge, LA, USA.
- Grizzle, R.E. and M. Brodeur, 2004. Oyster (*Crassostrea virginica*) reef mapping in the Great Bay estuary, New Hampshire. pdf Final Report to the New Hampshire Estuaries Project, 19pp.
- Grizzle, R.E., L.G. Ward, J.R. Adams, S.J. Dijkstra, and B. Smith, 2005. Mapping and characterizing oyster reefs using acoustic techniques, underwater videography, and quadrat counts. pp. 153-160, In: Benthic Habitats and the Effects of Fishing. P.W. Barnes and J.P.

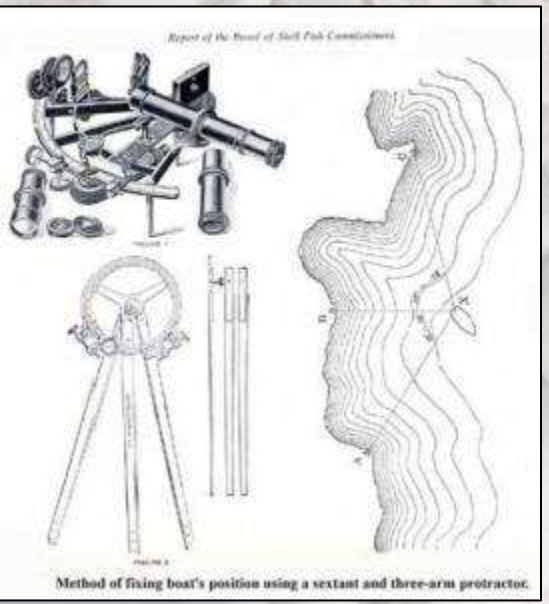
Just Out



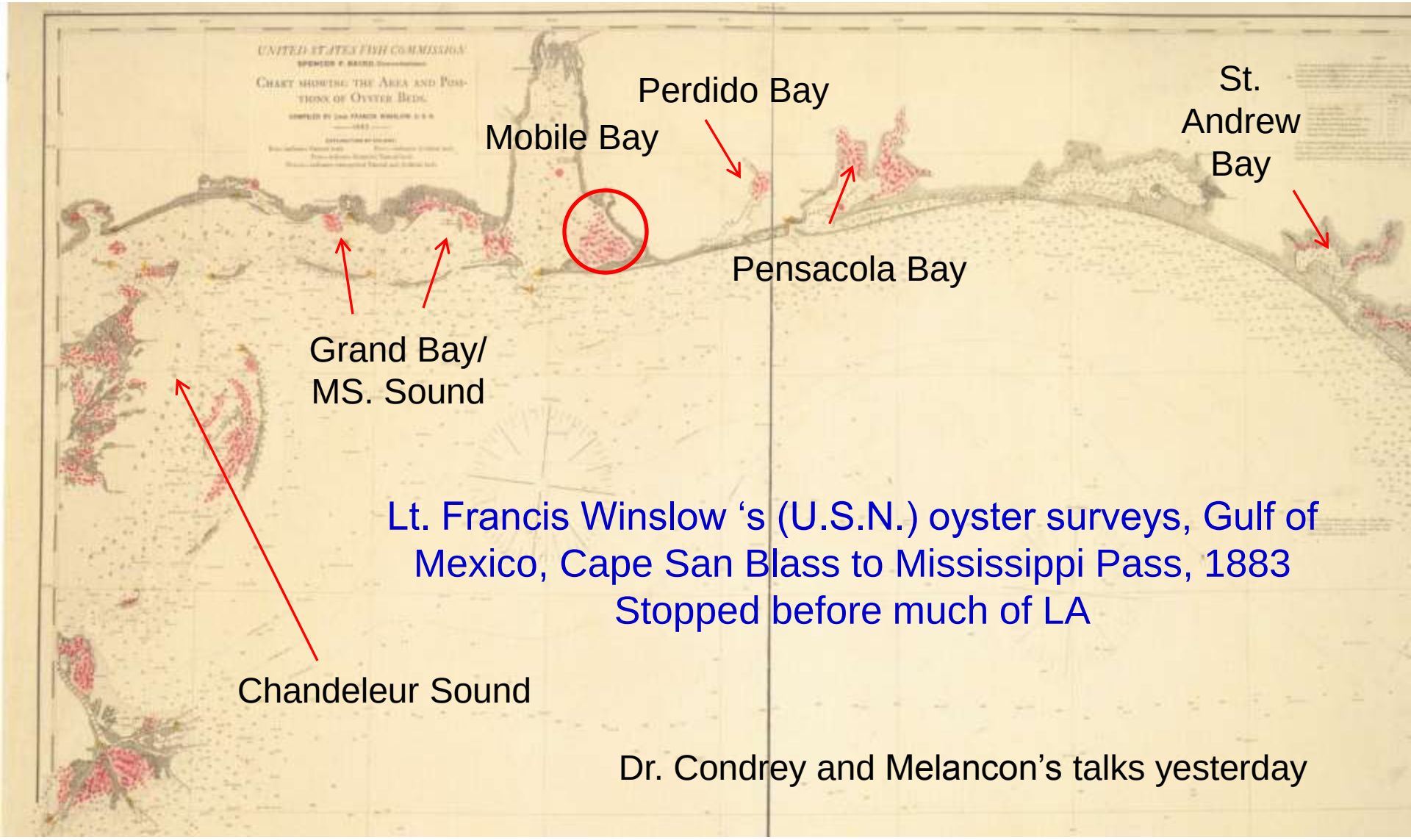
National Research Council (NRC), 2017. Effective monitoring to evaluate ecological restoration in the Gulf of Mexico. Committee on Effective Approaches for Monitoring and Assessing Gulf of Mexico Restoration Activities, National Academies Press, Washington, D.C., 219pp. see http://www.nap.edu/read/23476/chapter/1

Mapping of Shellfish Habitats

"During the winter of 1890-91, the Fish Commission steamer *Fish Hawk* was detailed to investigate the coastal waters of South Carolina, with the object of determining the position, extent, and characteristics of the natural oyster beds, and also of the bottom areas not now producing oysters, but suitable for their cultivation."


Method of fixing boat's position using a sextant and three-arm protractor.

Oyster Reefs at Risk Report: Historical 'Baseline' 'Maps (Fisheries)



Lt. Francis Winslow 's (U.S.N.) oyster surveys, Gulf of Mexico, Cape San Blass to Mississippi Pass, 1883
Stopped before much of LA

Dr. Condrey and Melancon's talks yesterday

Maps, Assessments of Shellfish

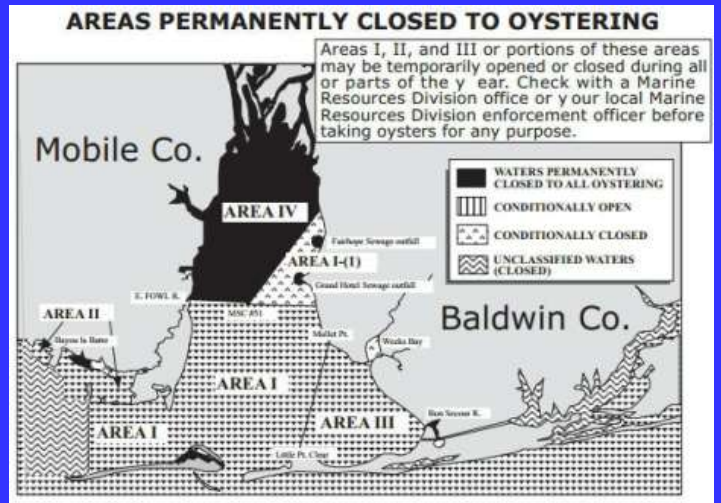
SARASOTA COUNTY
WATER QUALITY PLANNING

METHODS MANUAL FOR FIELD
MAPPING OF OYSTERS

January 1, 2011

Kathryn L. Meaux
Environmental Scientist
Sarasota County

Sarasota County



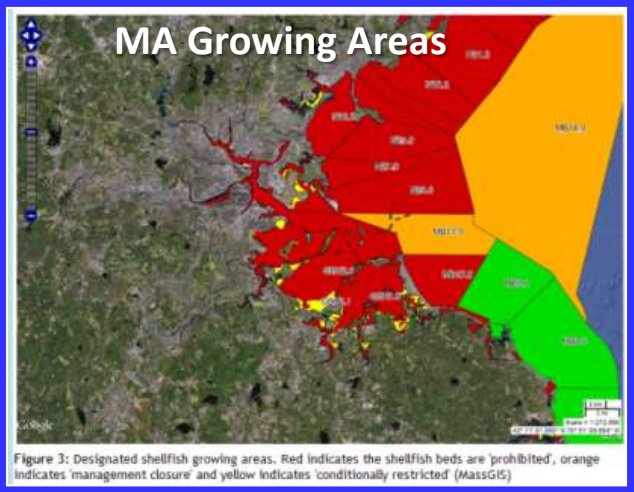
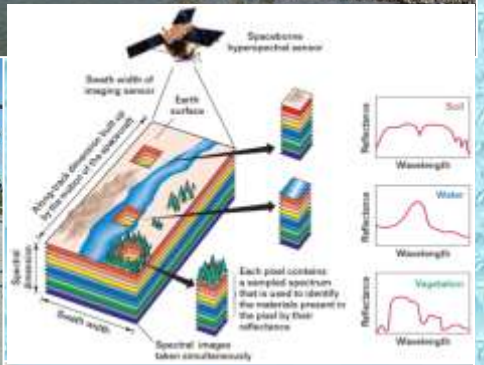


Figure 3: Designated shellfish growing areas. Red indicates the shellfish beds are 'prohibited', orange indicates 'management closure' and yellow indicates 'conditionally restricted' (MassGIS)

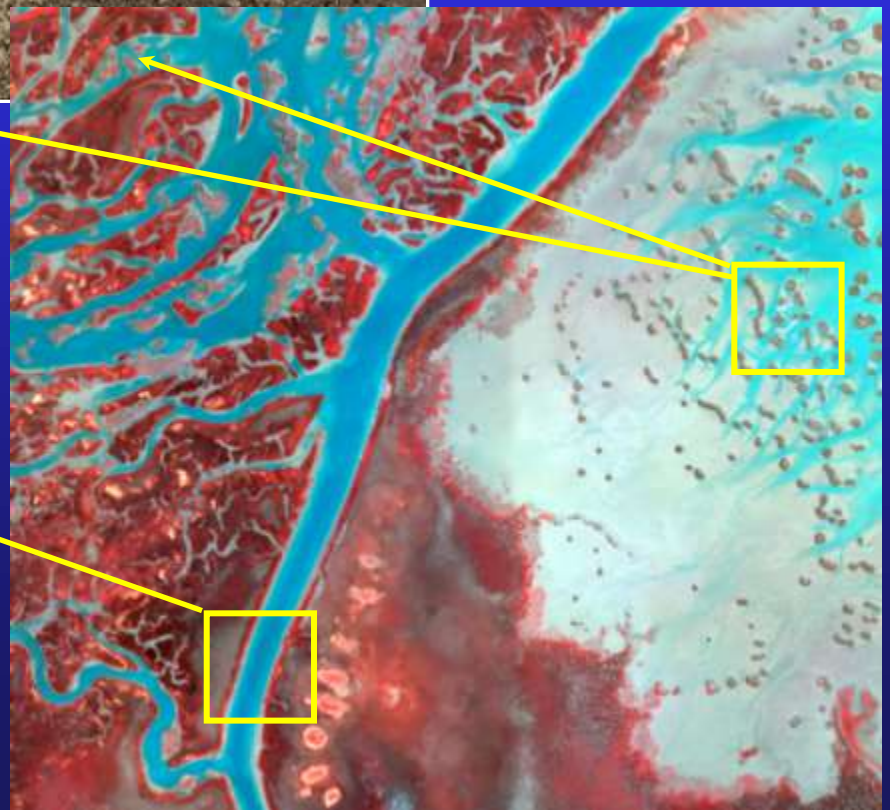
Assessing and Mapping Oyster Habitats

1) Questions of interest
2) Reef Type (dictates equip.)
    I. Intertidal
        i. Tidal range, accessibility
    II. Subtidal
        i. Depth, tidal range, accessibility
3) Scale
    I. 10-100s km
    II. Hectares (acres)
    III. Meters
    IV. Sub-meter
4) Resources (logistics, $, hardware, vessels, processing, personnel, etc.)
    I. High tech to low tech ($$$$-$)
5) Often been done for research or pilot efforts only

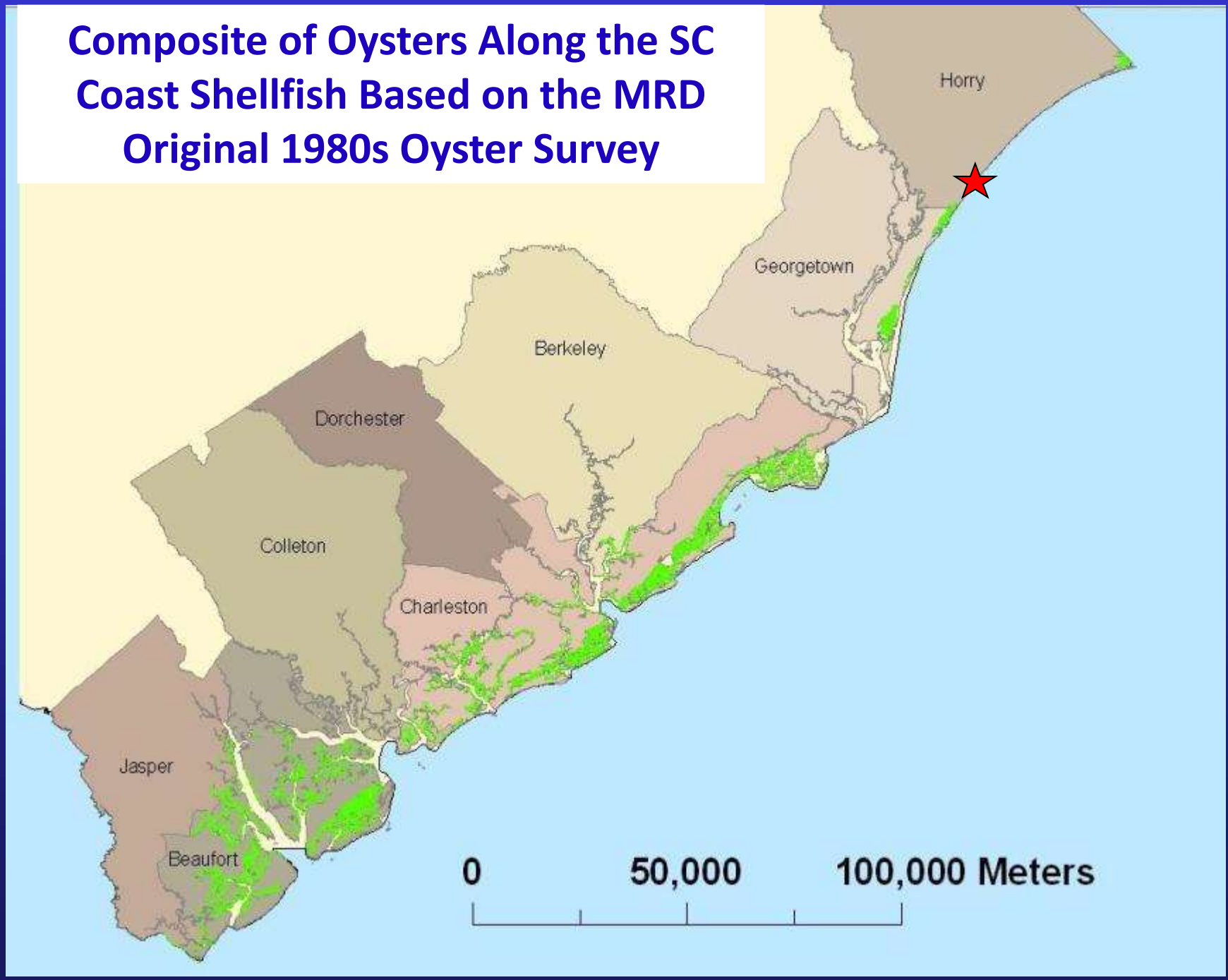


Typical Intertidal Oyster Reef Habitats

(see ASMFC 2007, Coen and Grizzle)



Composite of Oysters Along the SC Coast Shellfish Based on the MRD Original 1980s Oyster Survey



Some States Are Mapping Entire Coastlines: 100s Km

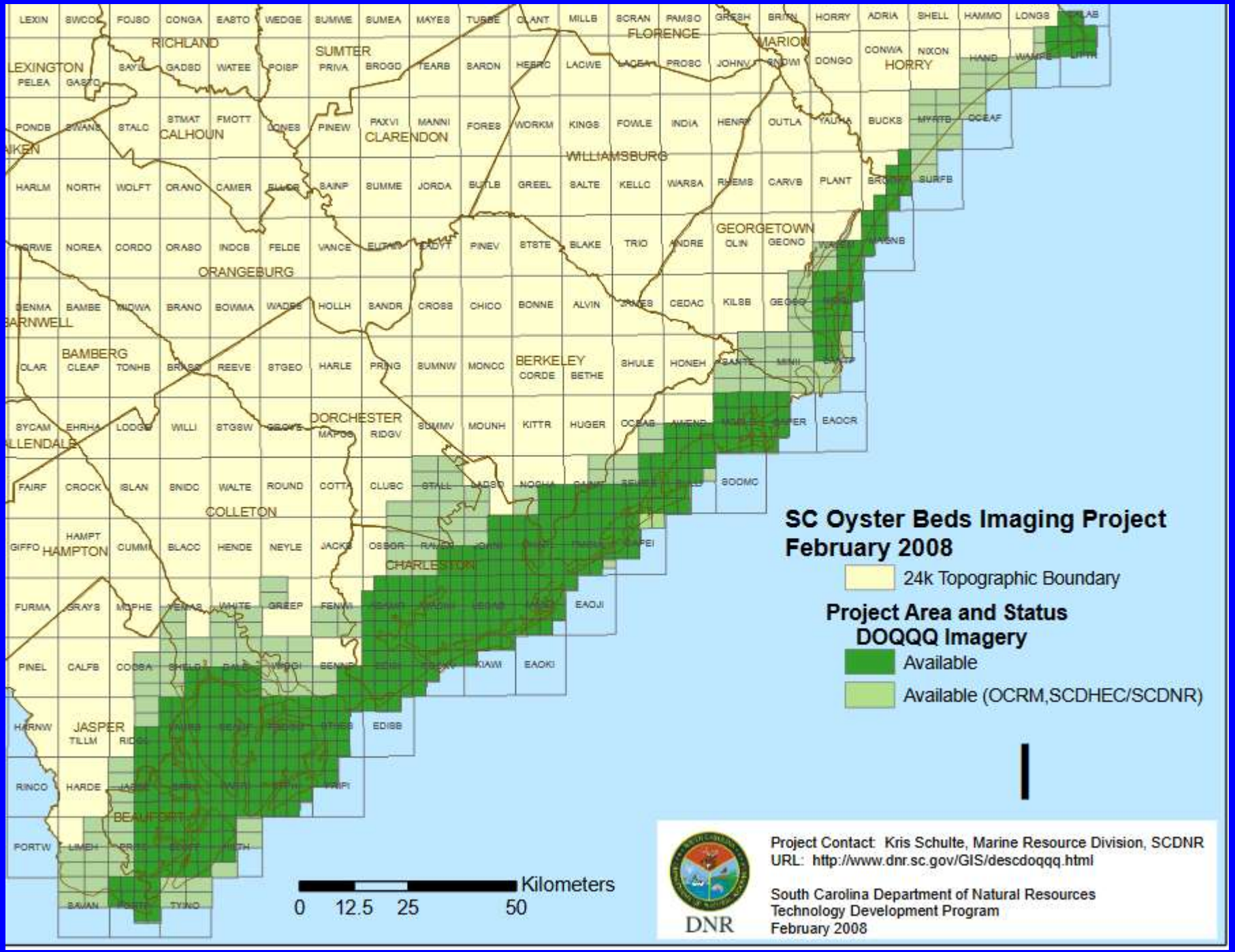
A Comprehensive Assessment of South Carolina's Intertidal Oyster Resources/Habitats Using High Resolution, Multi-spectral Digital Imagery for Management & Restoration

L.D. Coen, K.E. Schulte, G.M. Yianopoulos, R.F. Van Dolah, W.D. Anderson, all formerly at MRD-SCDNR, Charleston, SC

M.A. Finkbeiner & W.R. Stevenson, Coastal Services Center, NOAA, Charleston, SC

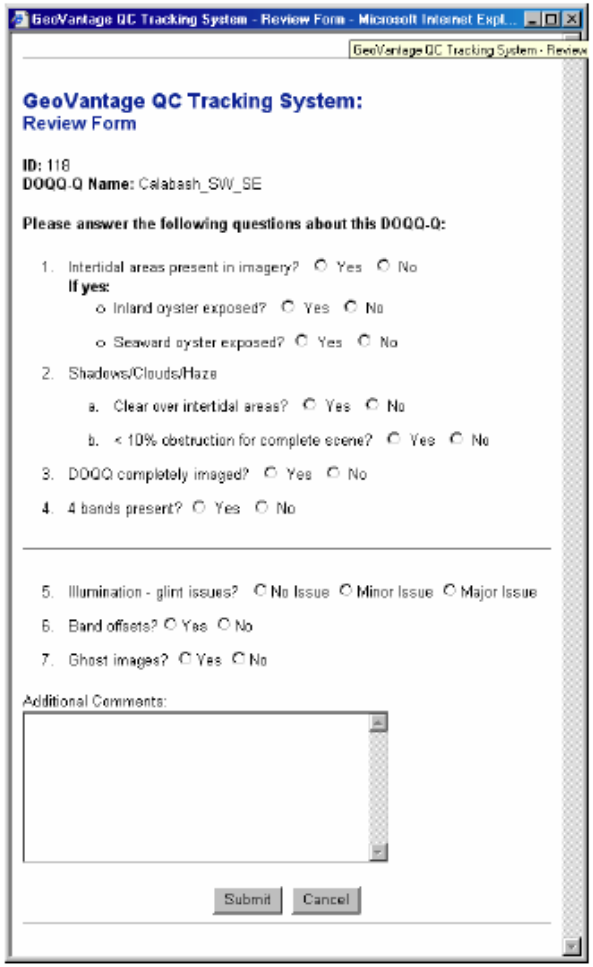
https://scdnr.maps.arcgis.com/apps/webappviewer/index.html?id=5bc898b455be43bea4a908491d2b3414

http://www.dnr.sc.gov/GIS/descoysterbed.html


SC Oyster Beds Imaging Project
February 2008
24k Topographic Boundary
Project Area and Status
DOQQQ Imagery
Available
Available (OCRM,SCDHEC/SCDNR)
Kilometers
0 12.5 25 50
DNR
Project Contact: Kris Schulte, Marine Resource Division, SCDNR
URL: http://www.dnr.sc.gov/GIS/descdoqqq.html
South Carolina Department of Natural Resources
Technology Development Program
February 2008

Review of Imagery and Related Issues (CSC)

Using the Review Form



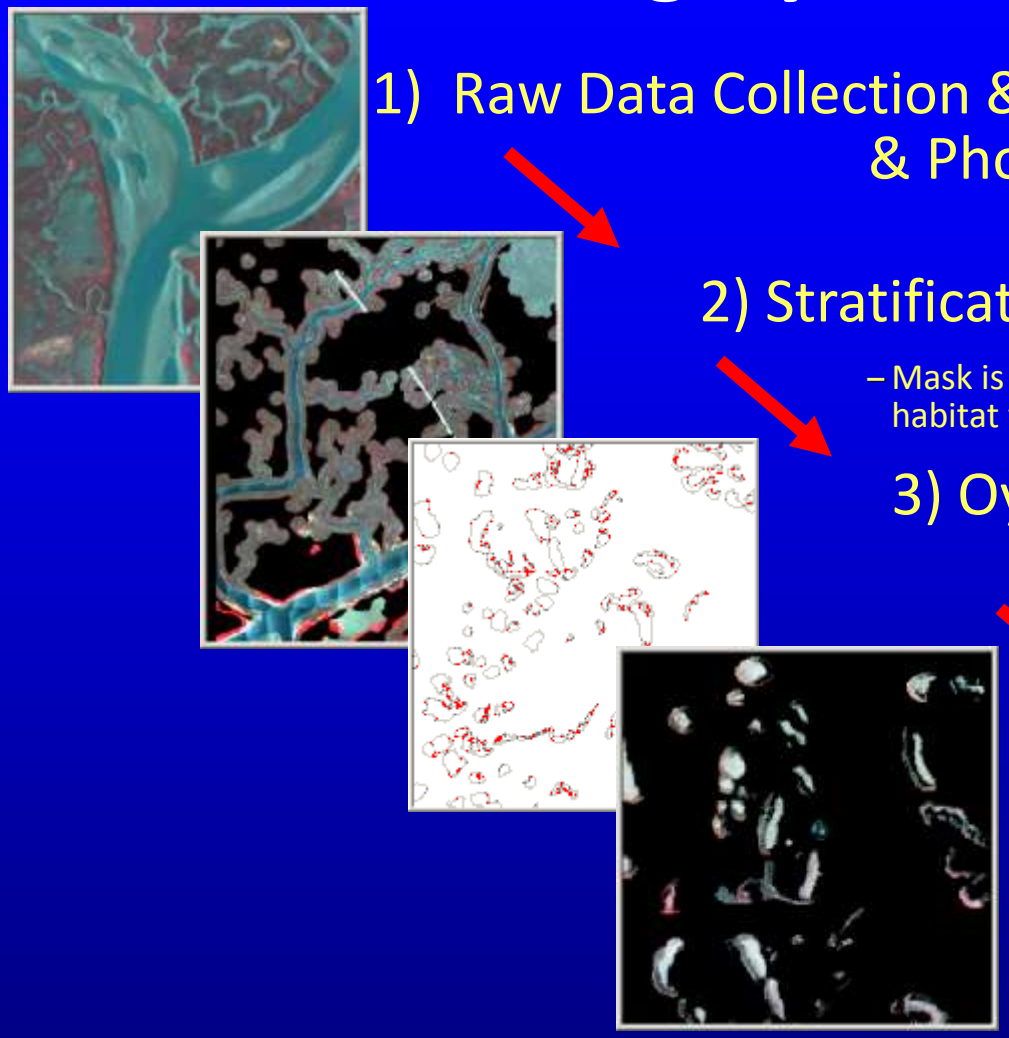
The review form has a logic process behind it that takes the information entered for each parameter and bins the image into one of three bins – accepted, rejected, or not useful for mapping.

To be **accepted**, the reviewer must answer YES to the first four questions and NO to the last three.

To be rejected, the review must answer NO to ANY of one of the first four questions or YES to ANY of the last three questions. Once an image is rejected, it will be reviewed by one of the project principles prior to being re-flown or re-processed.

To be binned as not useful for mapping, the reviewer must answer NO to Question 1 – Intertidal areas present in imagery?

Imagery Classification



1) Raw Data Collection & Rectification by GeoVantage & PhotoScience

2) Stratification of Oyster Habitat

- Mask is created for areas not containing oyster habitat through the use of buffers with ERDAS' Imagine®

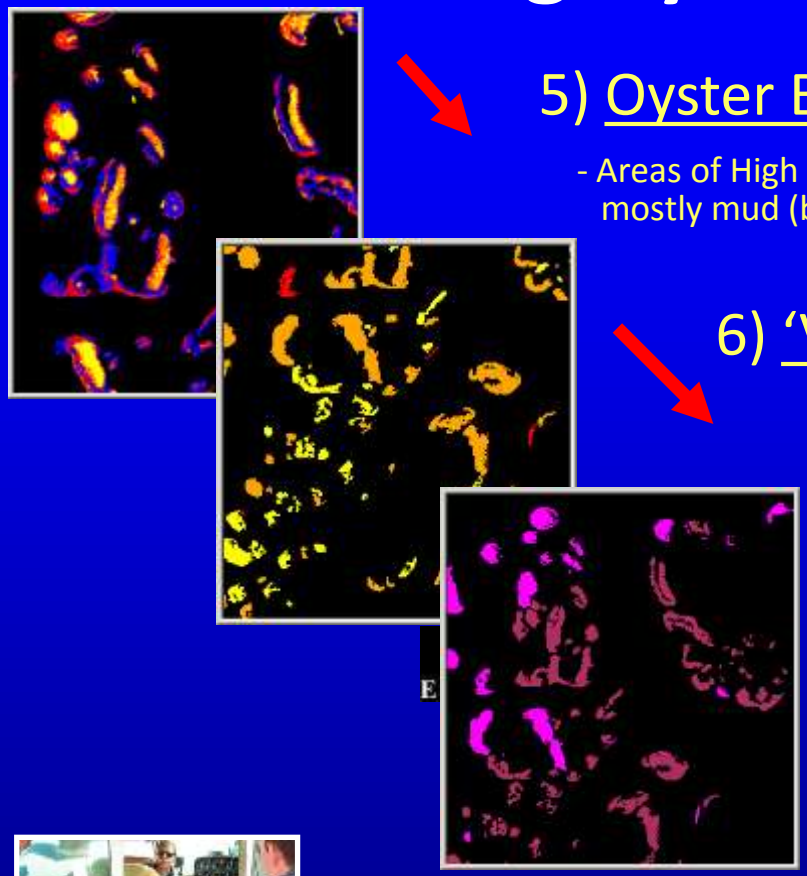
3) Oyster Beds Delineated

- Computer trained to identify oyster 'signatures' in each image using Feature Analyst®

4) Raw Data Stratified

- Areas not containing oysters are removed using ERDAS' Imagine®

Imagery Classification cont.



5) Oyster Beds Classified

- Areas of High (red), Medium (orange), Low (yellow) & mostly mud (blue) are classified with ERDAS's Imagine®

6) 'Verticalness' Characterized

-Through clump analysis each bed is characterized as either High, Medium, or Low '% vertical shell' in ERDAS's Imagine®

7) Strata Characterized

- Using a 'rule-set' based on the % from step 5, ERDAS's Imagine® determines the 'majority' strata

Midway shifted from GeoScanner to Photo Science's DMC (remaining 30%) imaging platform:

Differences: 12 bit/pixel vs. 8 bit radiometric resolution, spectral resolution, spatial resolution format, sensor format, software retraining

Ground-truthing: Used Classified Imagery, Ground Images, Video, dGPS, and Helicopter

Detailed Process

- Ground-truthed before classified images received
- 75-100 beds selected randomly in each DOQQ
- GPS 'points' taken at the start/end of a bed = 'transect'
- 30-40, non-oyster transects collected (assess 'false positives')
- Reefs 'characterized' & mean bed width estimated

A Trimble Pathfinder Pro XR Surveying GPS system is used (submeter accuracy)

Consensus of Mapping Group, in Order of Importance for Post-processing of Ground-truthing Assessments

Priority 1: QC presence/absence of beds (=polygons);

Priority 2: Classify beds (=polygons) using the combined (3-4, reduced strata types, formerly 9) for each polygon using the MMU (10 m^2) polygons may have multiple classifications;

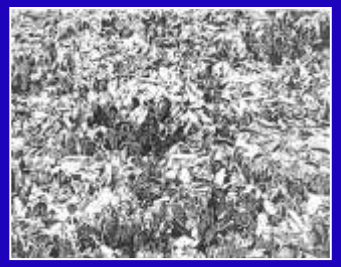
Priority 3: Estimate areal extent of a given subset of polygons within each DOQQQ; and

Priority 4: If possible, estimate shell 'density', % shell cover within polygon

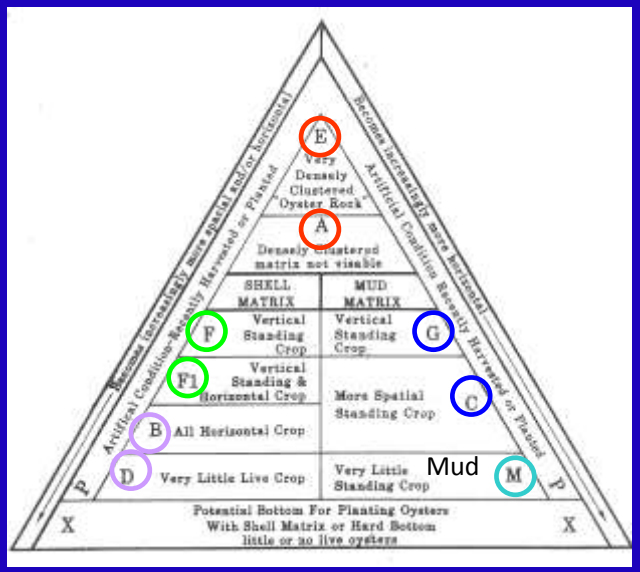
Suggested OFM Intertidal Strata

(strata with same color not distinguished)

Strata A



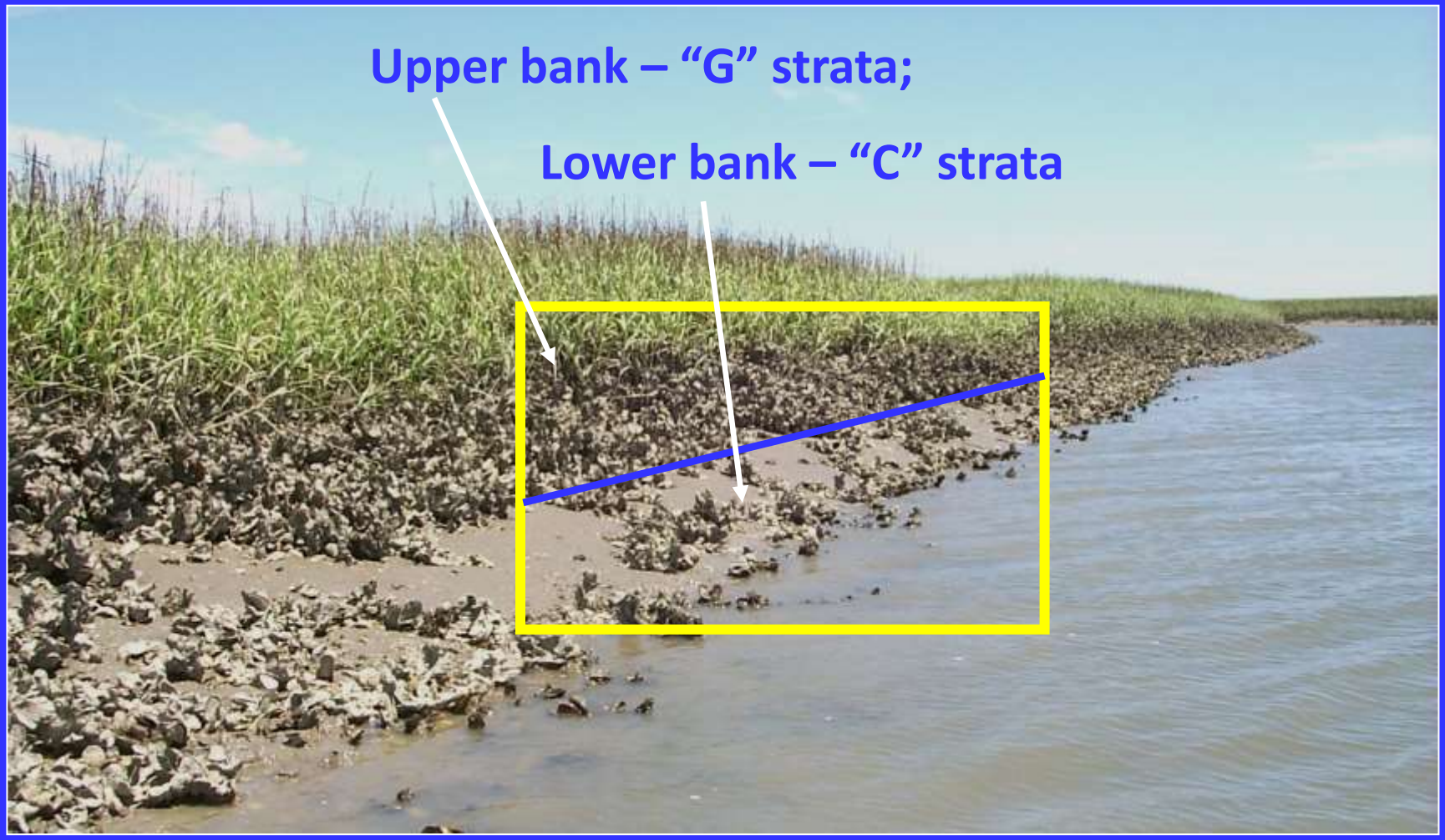
Strata F



Strata C

Strata G

Polygons May Have Multiple Classifications



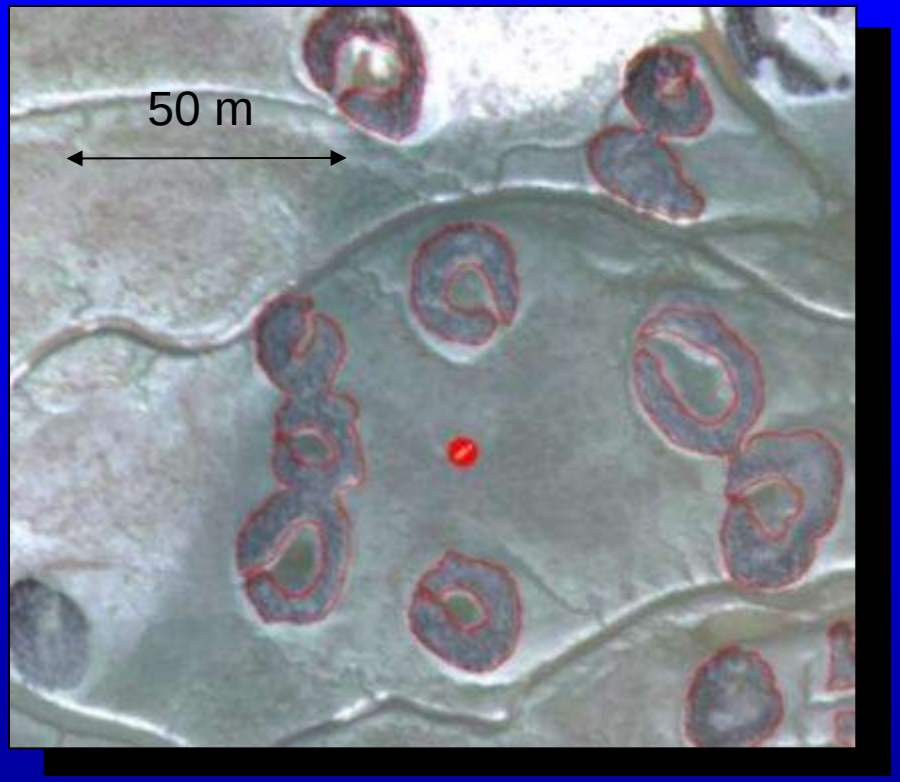
Ground-Truthing By Helicopter

- For large “oyster flats” areas inaccessible by boat at low tide and walking, digital pictures are taken at ~122 m
- dGPS location is taken with each image to pinpoint footprint on DOQQ later

FUTURE: OnyxStar HYDRA-12, *heavy lifter drone (payloads to 12 kg)*

http://www.onyxstar.net/hydra-12/

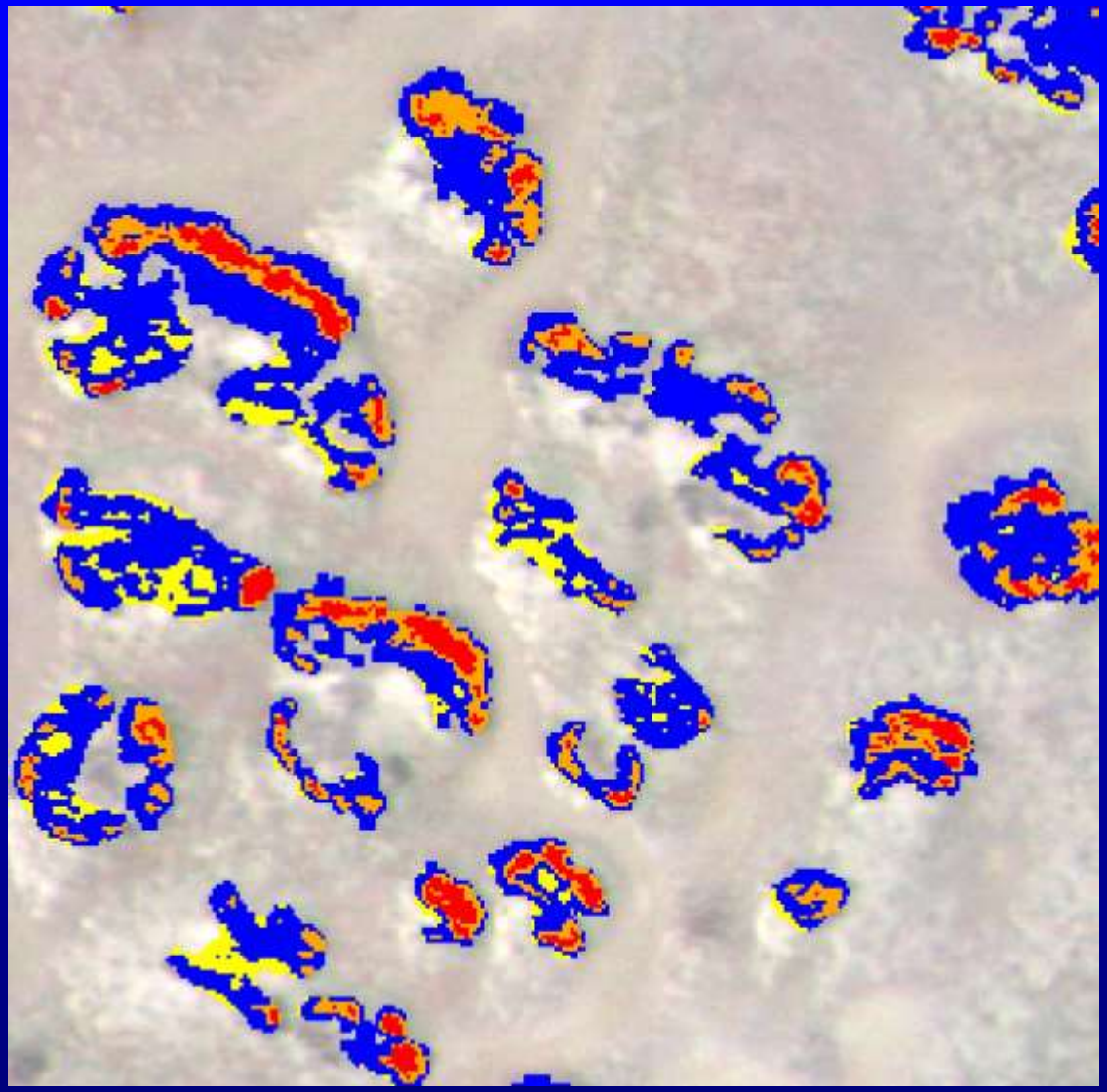
Groundtruthing - Helicopter



- ✓ Helicopter digital photograph
- ✓ Multi-spectral imagery with hand-digitized polygons (in red)

Imagery Classification:

(see earlier slides, steps 1-7)



Oyster Restoration in an Urban Landscape: Lynnhaven, VA

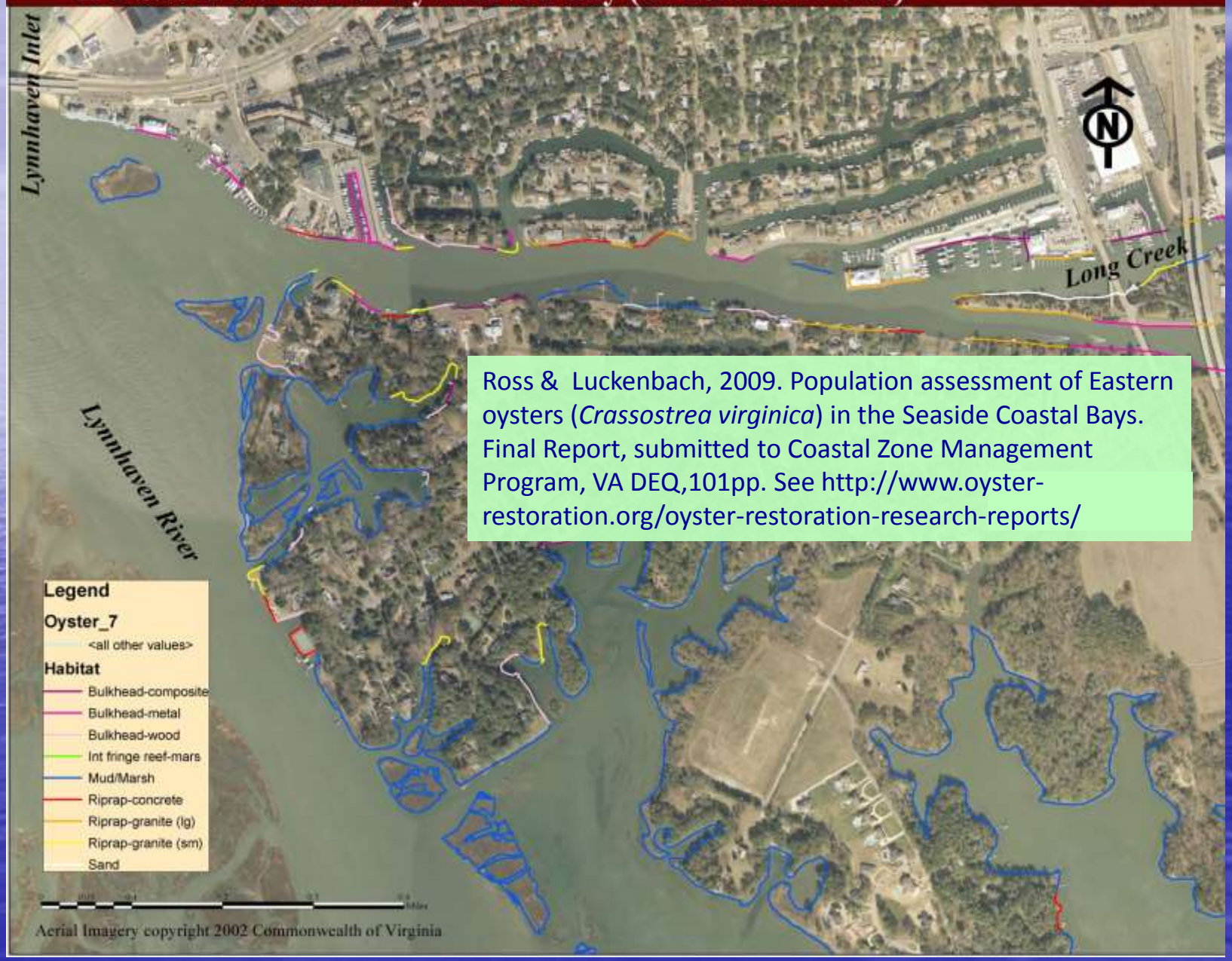
Value of Other Substrates

40% of live oysters were found in "non-traditional" habitats that typically would NOT be sampled in a typical 'fishery-only based' assessment

WILLIAM & MARY VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

NOAA CHESAPEAKE BAY

Lynnhaven Bay Basin, Virginia Beach, VA 2002
Lynnhaven Inlet and Long Creek to Great Neck Rd. Bridge & Eastern Portion of Lynnhaven Bay (Great Neck Point)

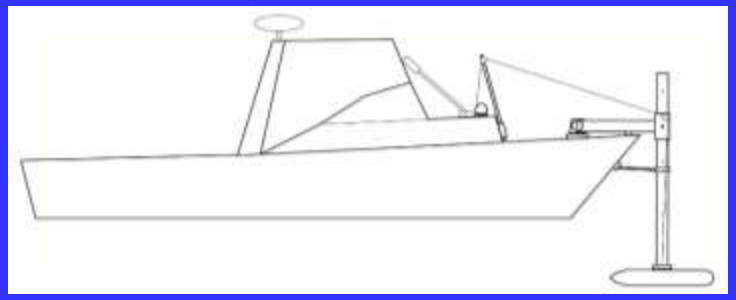


Ross & Luckenbach, 2009. Population assessment of Eastern oysters (*Crassostrea virginica*) in the Seaside Coastal Bays. Final Report, submitted to Coastal Zone Management Program, VA DEQ,101pp. See http://www.oyster-restoration.org/oyster-restoration-research-reports/

Provincetown
Center for Coastal Studies

High Frequency Sidescan Sonar to Map Shellfish Habitat and Estimate Population

Mark Borrelli et al., Dept. of Marine Geology

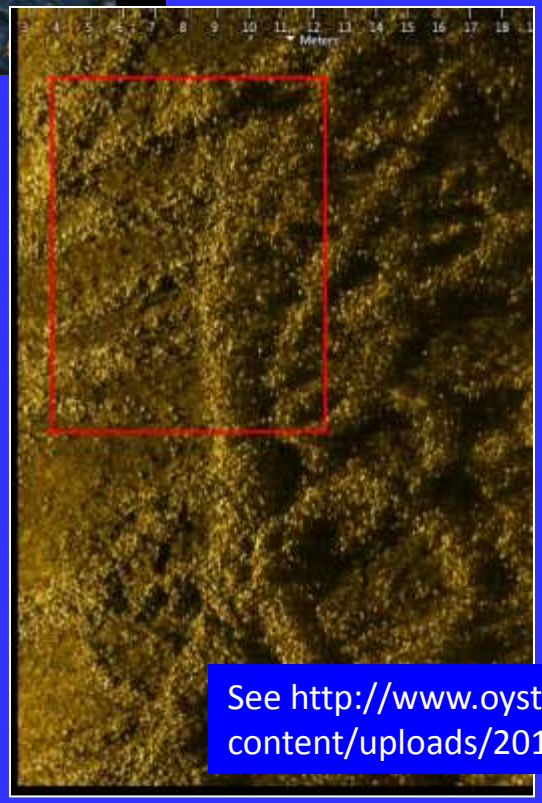


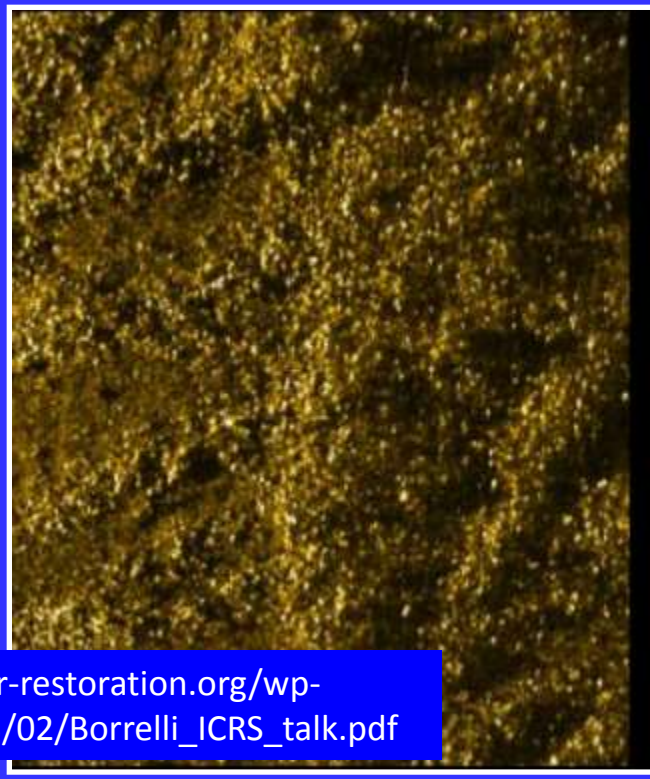
Initial Findings:

- Establish quantitative relationship between oysters in life position and sidescan sonar data
- Ground validation (GT) of:
  - reef area
  - reef height
  - oyster density/recruitment
- Return using sonar and GT surveys

Interferometric bathymetry system has an average swath:depth of 10:1 vs. typical multi-beam sidescan at 3:1

http://coastalstudies.org/programs/marine-geology/seafloor-mapping/

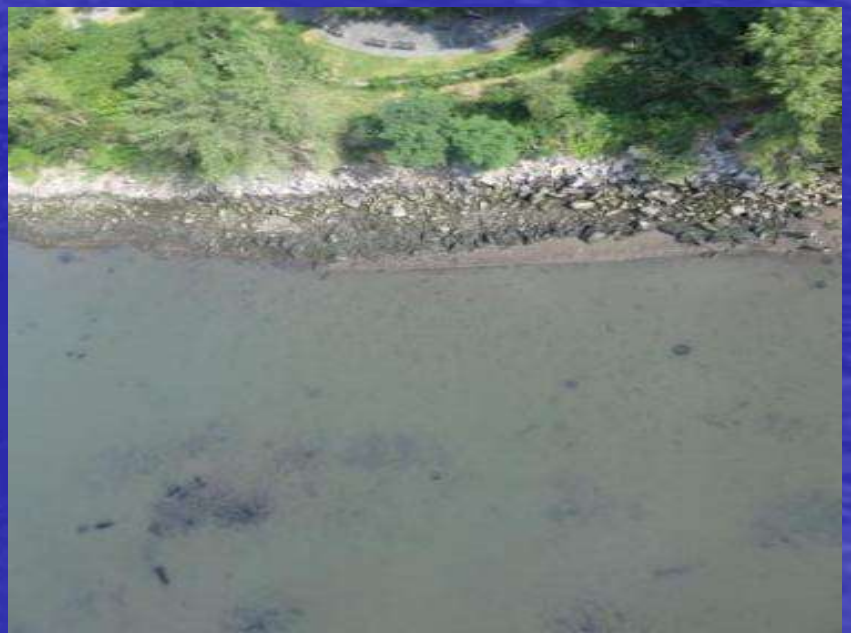




See http://www.oyster-restoration.org/wp-content/uploads/2013/02/Borrelli_ICRS_talk.pdf

Mapping Site at Sound View Park, Bronx, NY

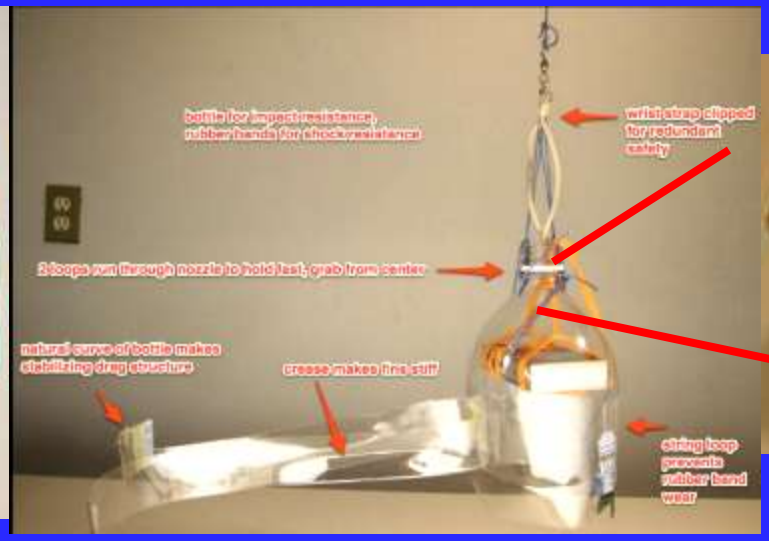
See: http://publiclab.org/notes/liz/8-21-2012/bronx-river-soundview-park-oyster-reef-mapping



Larger-Scale: Helium Balloon With Digital Camera Set-Up

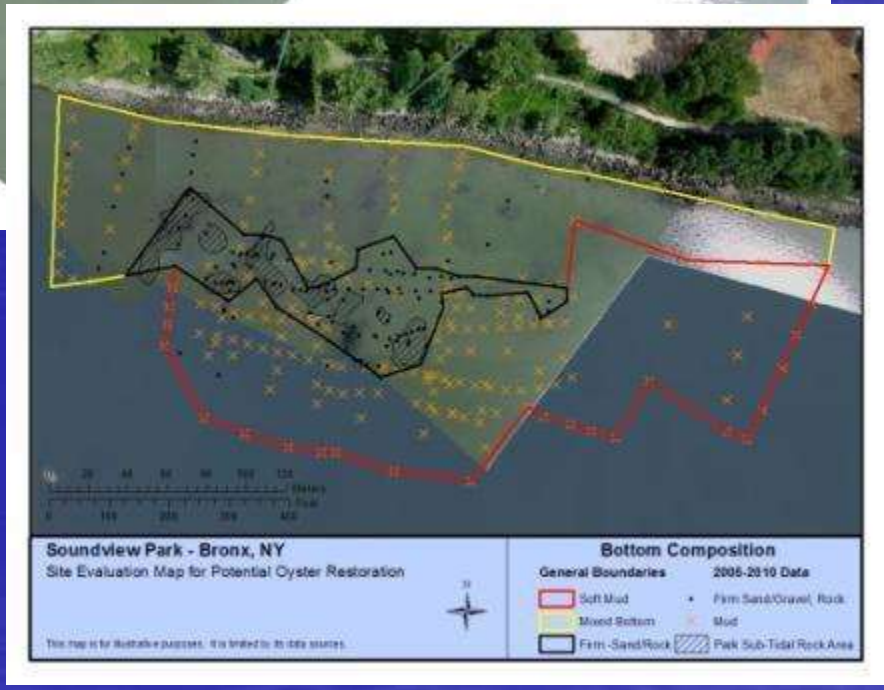
Whole kit:

- ✓ Buy their balloon kit (~$95)
- ✓ Digital camera or Smartphone
- ✓ Trigger and simple housing (free)
- ✓ Get helium ($45-100 tank)
- ✓ Follow the pre-flight checklist(pdf) and Quickstart Guide (pdf)
- ✓ Use free Mapknitter or other to create “stitched” map



See http://publiclab.org/wiki/balloon-mapping

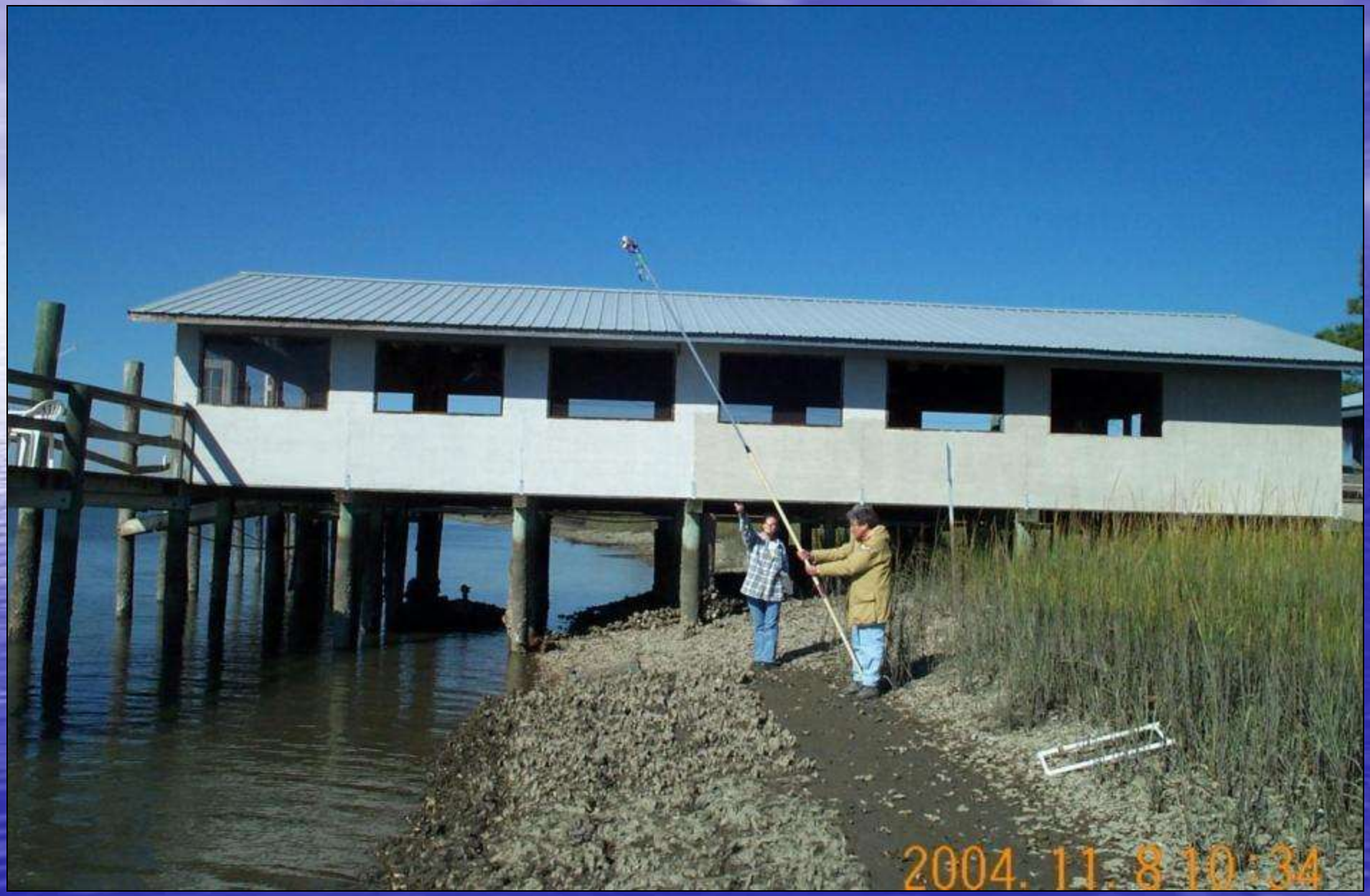
Stitched Images and GIS Maps



For More Information See:

- http://www.oyster-restoration.org/oyster-restoration-research-reports/
- http://publiclab.org/notes/liz/8-21-2012/bronx-river-soundview-park-oyster-reef-mapping
- http://mapknitter.org/

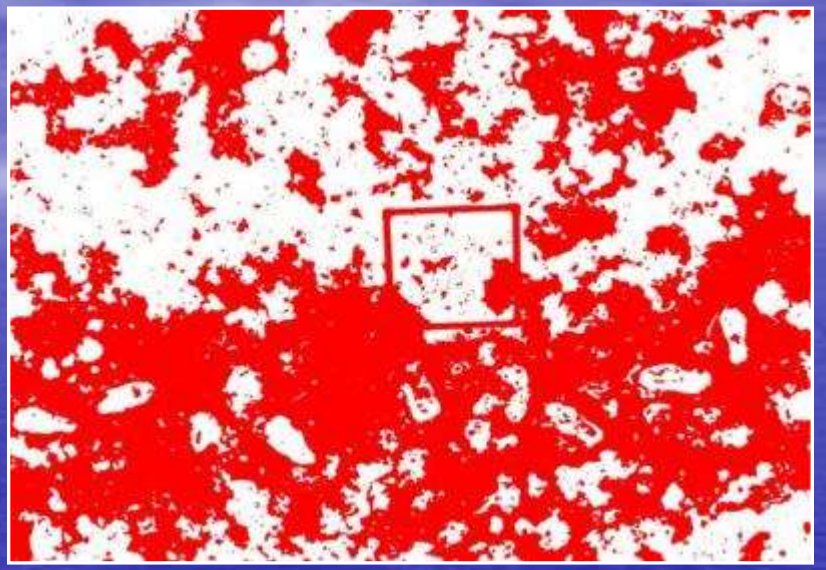
Small-Scale: Intertidal Overhead Digital Imagery



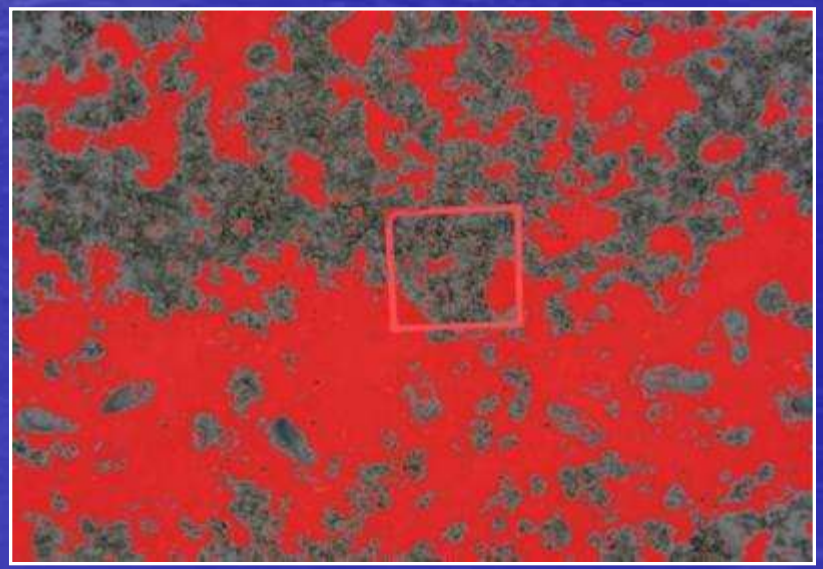
Small-Scale: Intertidal Overhead Digital Imagery

Original photo

Digitized mud areas (red)



Area with oysters/shell



52% Oyster Coverage
48% Mud

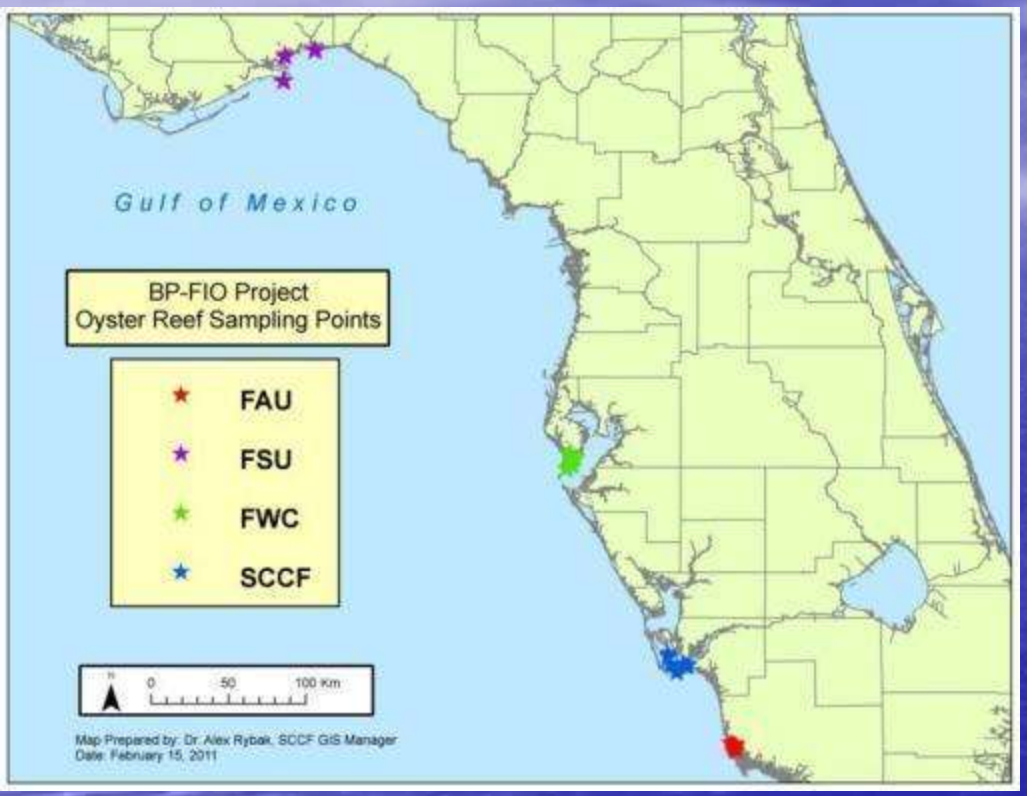
Low Tech Options: Meter Tape or Laser Rangefinder
Smaller-Scale Assessments, *Ostrea* (B. Kingzett, Nootka Sound)

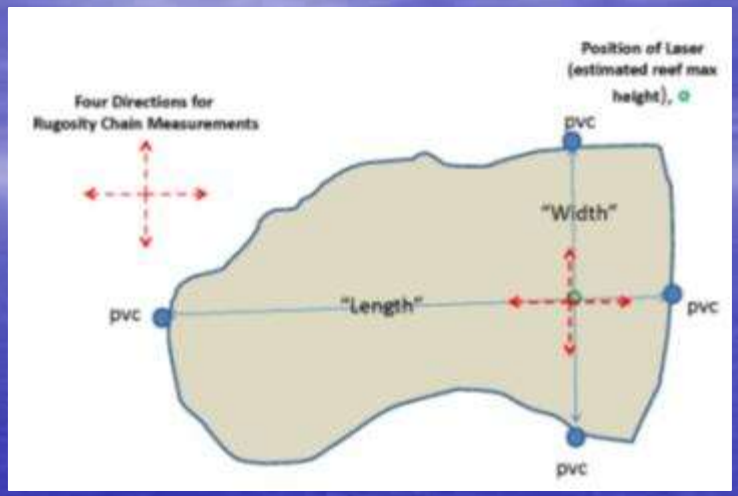
Wireless Dedicated Frequency Band Measuring System

Contact Coen for more info

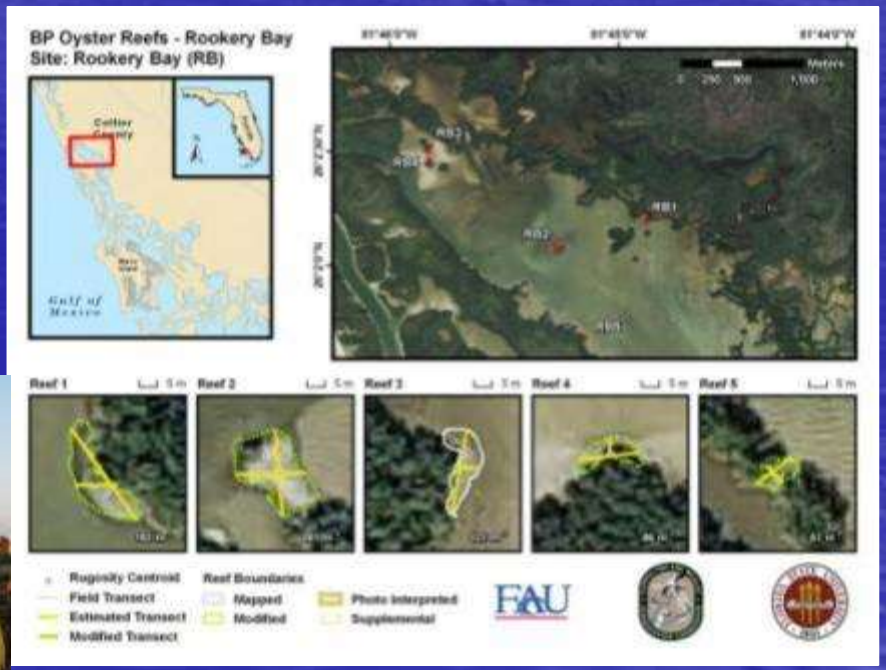
http://www.starrett.com/docs/other-downloadable-resources/datasure---bulletin-578.pdf

BP-FIO Grant: Natural Oyster Reefs in FL: FAU-HBOI, FSU, FWRI

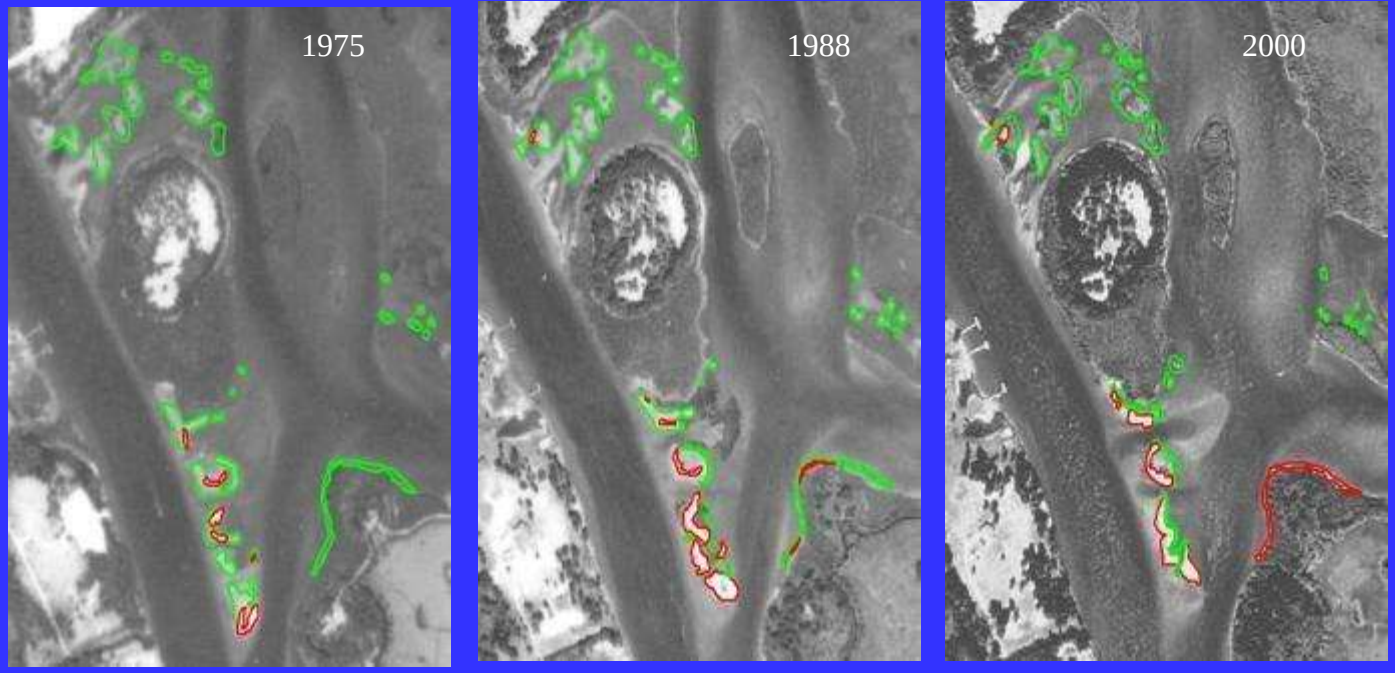




Used Identical Methodologies at all 60 Sites



Changing Natural Reef Habitats Through Time (km): Temporal FL Intertidal Reef Changes



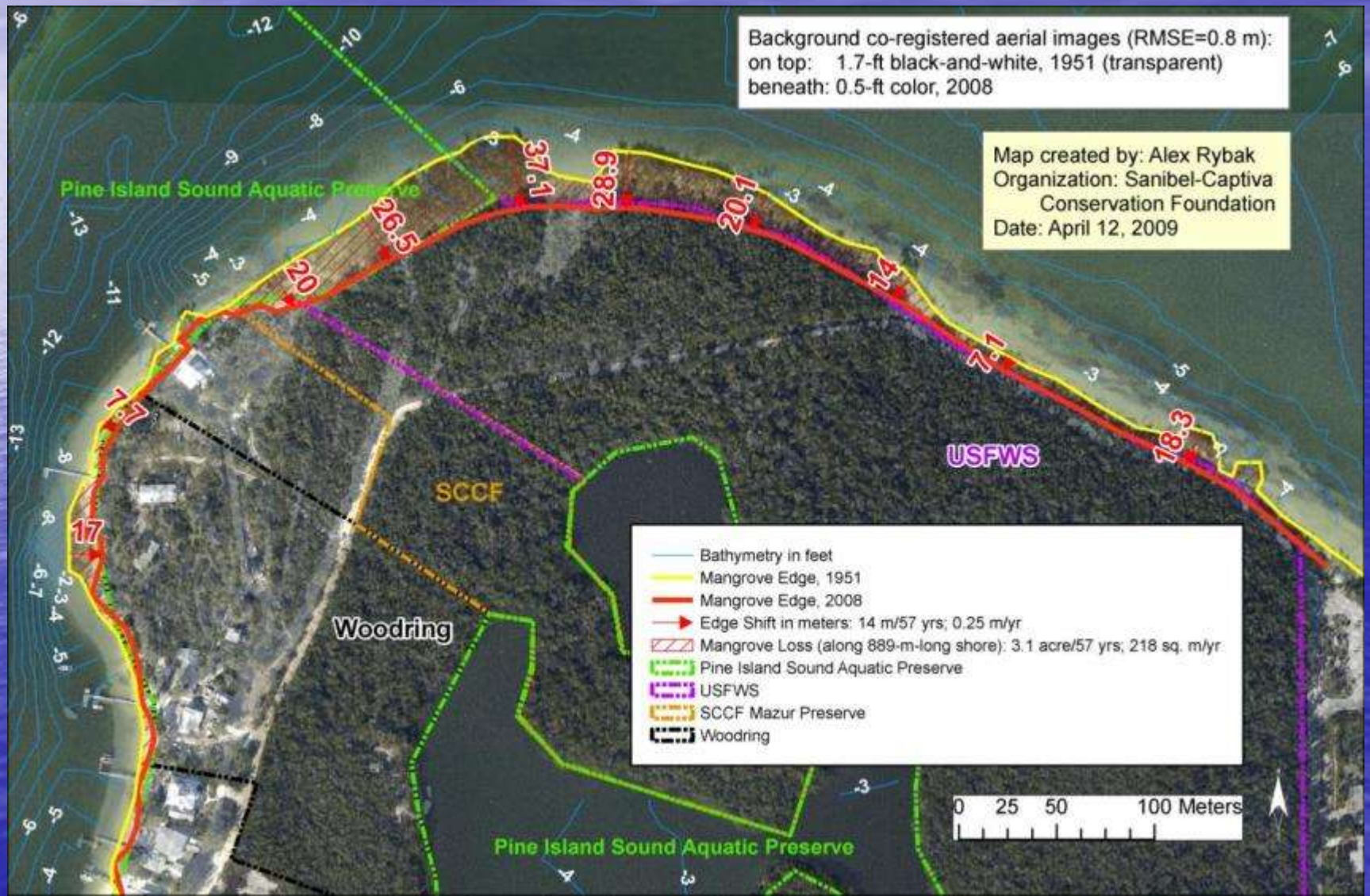
Intertidal oyster reefs (Canaveral National Seashore, CANA) Florida. Aerial imagery over **25 years** shows increased dead reef areas (red) compared to living (green), assumed most probably caused by increased boating activities along AICW (see Grizzle et al. 2002)

Shoreline Erosion: Reef & Marsh Change

A-C, images from helicopter ground-truthing, SCDNR (part of the remote sensing effort). Red highlighted areas marsh erosion/slumping

From helicopter over flights @~122 m (400') and ground assessments

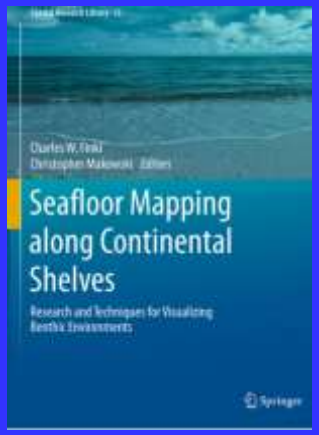
Assess Shoreline Change Using Existing Imagery



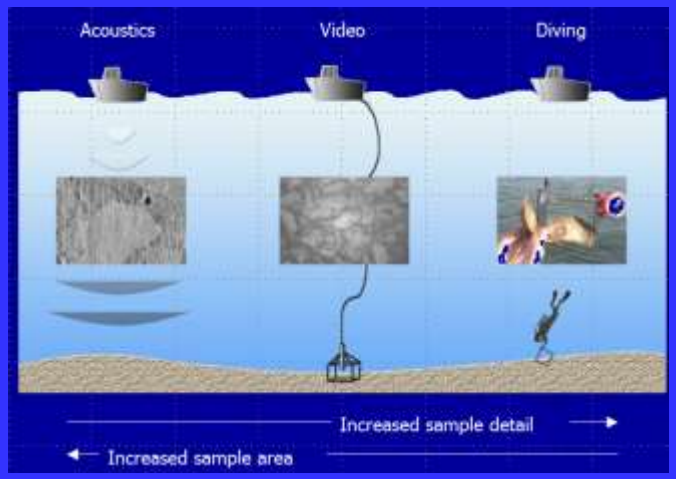
Subtidal *C. virginica* Oyster Reefs

From: K. Paynter, UMD

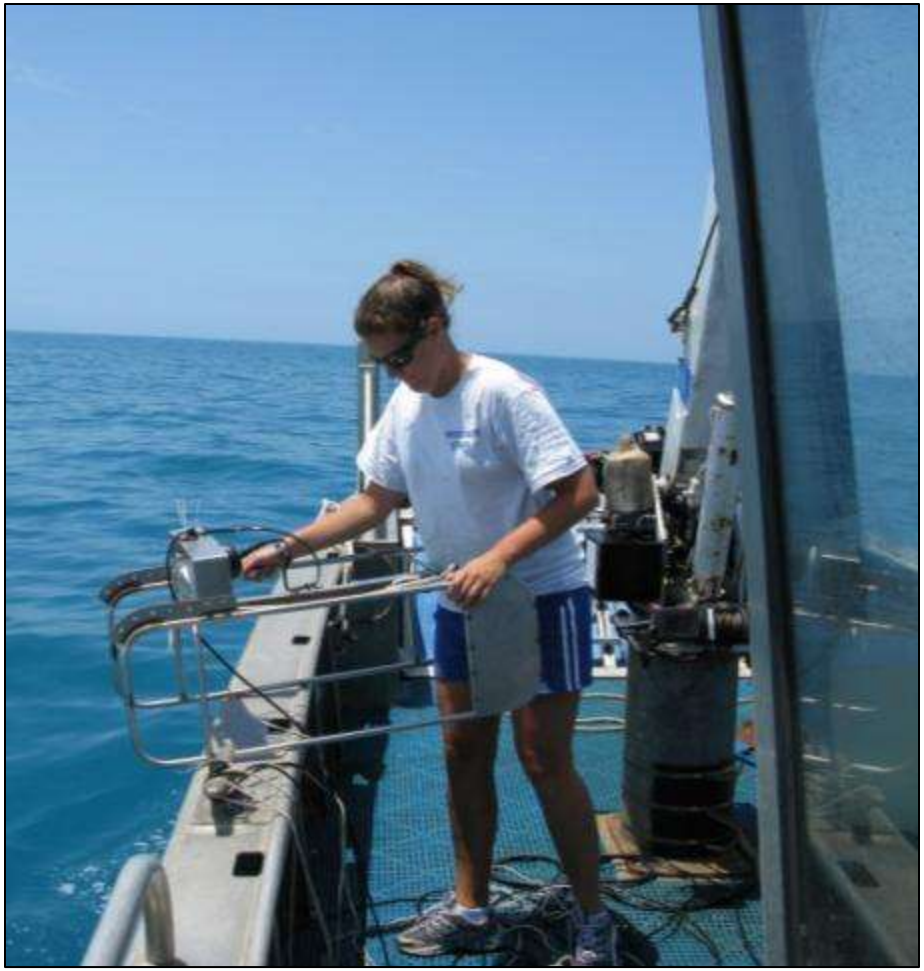
Problems Specific to Subtidal Mapping



1) Questions of interest
2) Visibility
3) Scale (m-km)
4) Depth (m)
    i. Swath width (narrow when shallow)
    ii. Concerns over hitting something with pricey hardware
3) Resources ($, hardware, single, multi-beam, other)
4) Mapping has been done over small scale at higher resolutions, for research or often as pilot efforts only

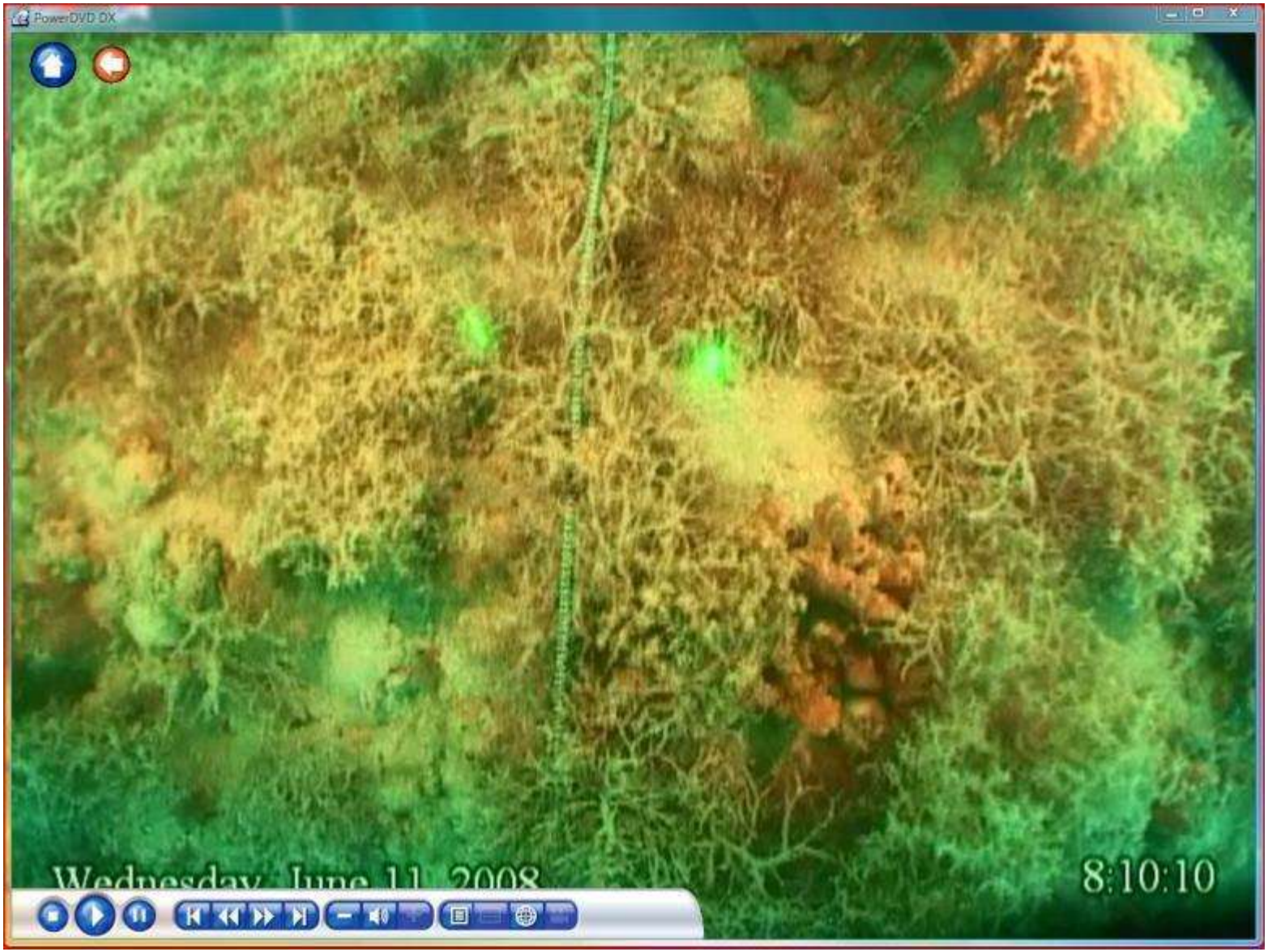


Bottom Habitat/Organism Mapping
Visibility Critical For Cameras



Off Sanibel Island,
Grizzle and Coen

Diver Transects for Bottom Mapping

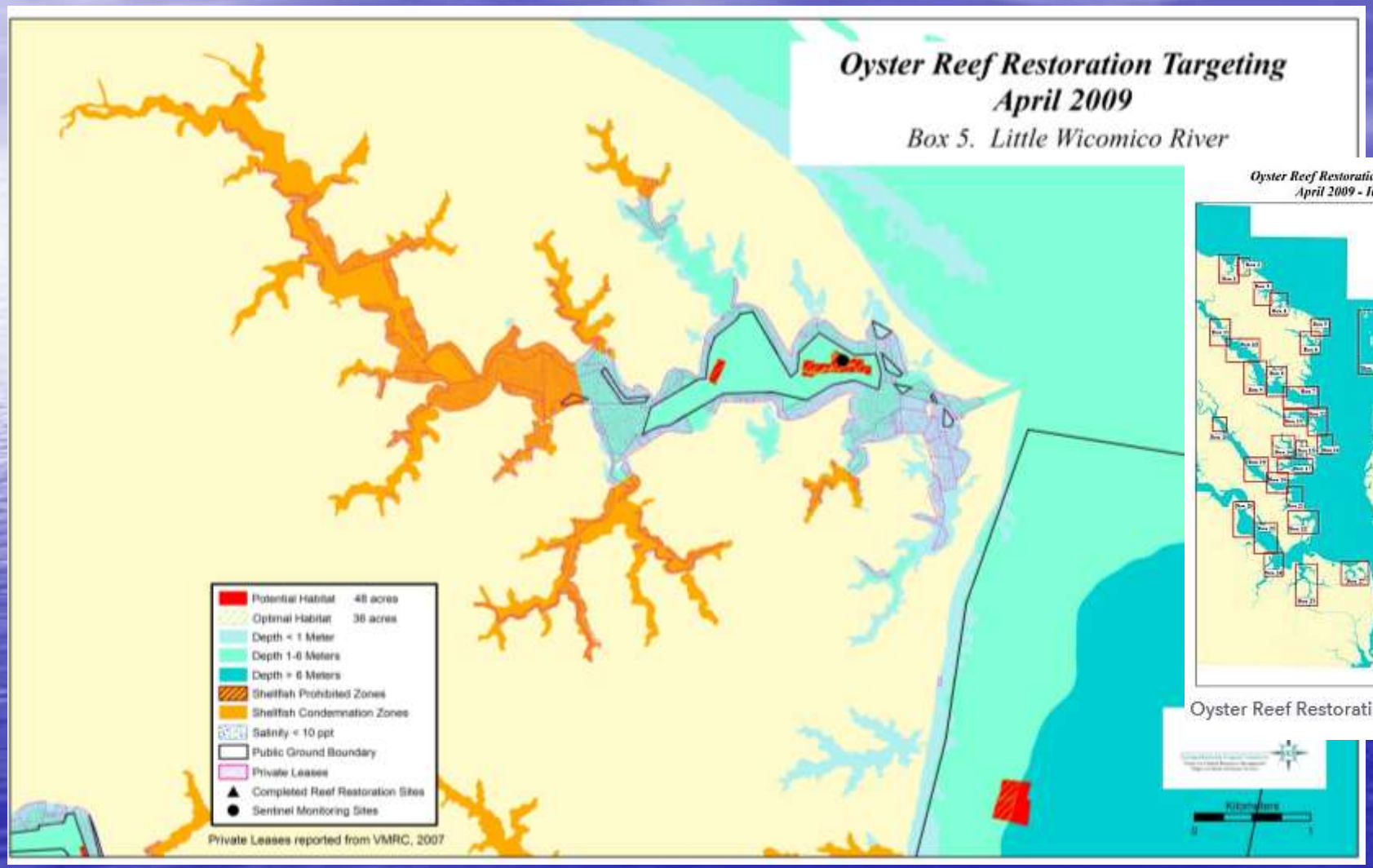


Milbrandt et al. drift algae study, SCCF

Remote Video Bottom Mapping

Coen et al. drift algae study, SCCF

Maps Can be Used to Site Future Restoration Efforts



http://ccrm.vims.edu/cascade_files/jpegs/jpegs/phase2_box5.jpg

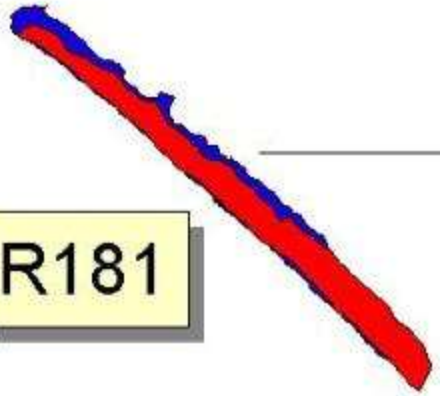
Mapping to Follow Constructed Oyster Reefs Through Time

Pre-planting Assessment, 7/02

Initial Planting ,7/30/02

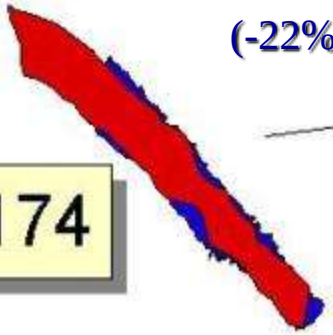
Two Years Post-planting, 4/15/04

Reef Footprint Changes Over Time: 10s-1000s m^2



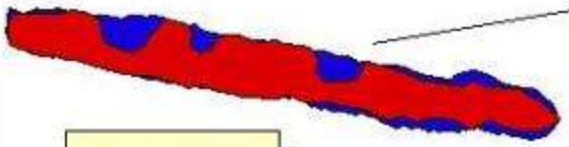
R181

(-22%)



R174

(+15%)



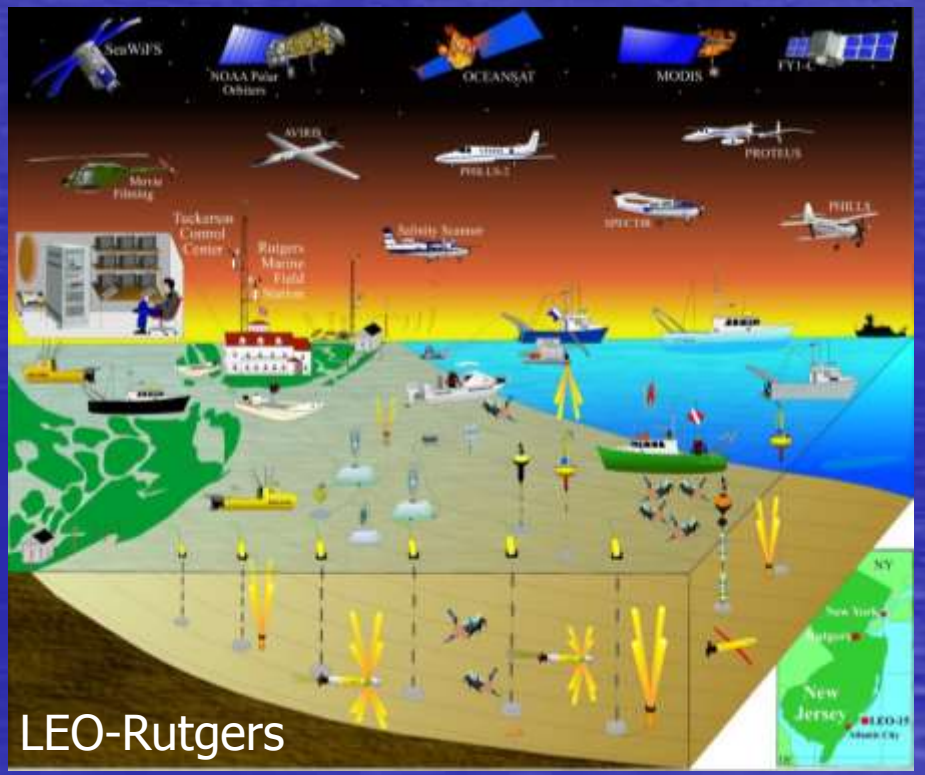
R175

(-21%)

Initial Planting 7/02/03
Planting Footprint 5/12/04

Footprint 5/12/04 – 252.2 m^2

The Future: Observing Systems



Acknowledgements

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Thanks for Invitation

Working on potential funding for new workshops with ESRI, Google, CSC-NOAA, TNC, NERRs, Others

FAU
FLORIDA ATLANTIC UNIVERSITY

ANY QUESTIONS/COMMENTS??

Jefferson: Charismatic Megafauna?