Accuracy of Protocols to Monitor Submerged Aquatic Vegetation at Sentinel Sites in North Carolina

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Submerged aquatic vegetation

- Seagrasses (*Zostera* and *Halodule* in NC) provide additional structure – soft bottoms, with structure for benthic invertebrates
- Infaunal clams are higher inside SAV beds than outside
- Blue crabs can not feed as well in SAV

Seagrasses

- Angiosperms (flowering plants) that live life entirely underwater
- Primary productivity is among the highest measured (500 - 4000 g C/m^2/year)
- Important feeding and refuge habitat for fishery species (shrimp, scallops, and fishes like flounder, sea trout, red drum, and forage fishes)
- Seagrasses act as sediment stabilizers help to filter water

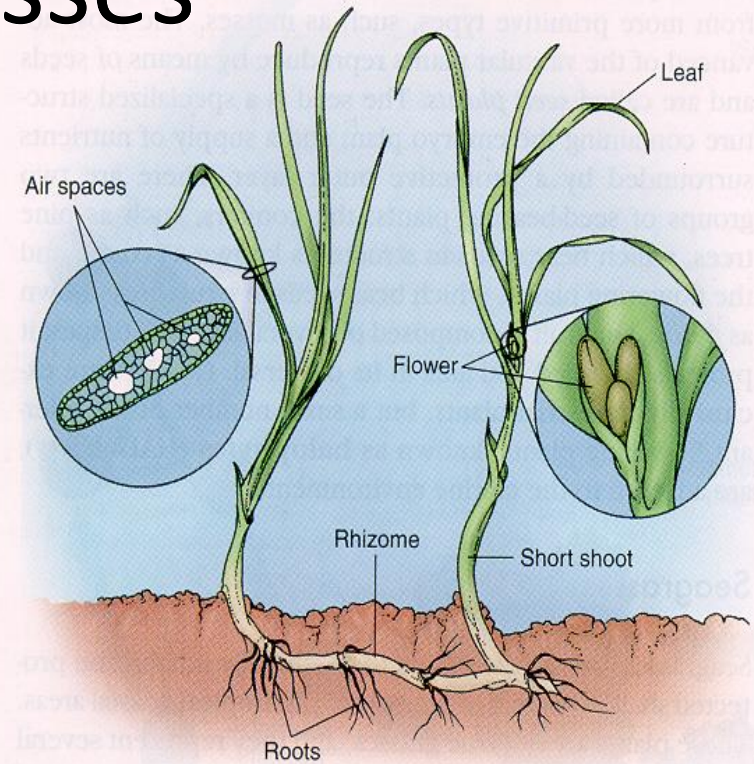
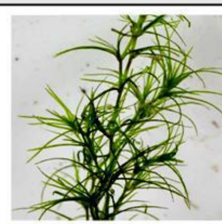
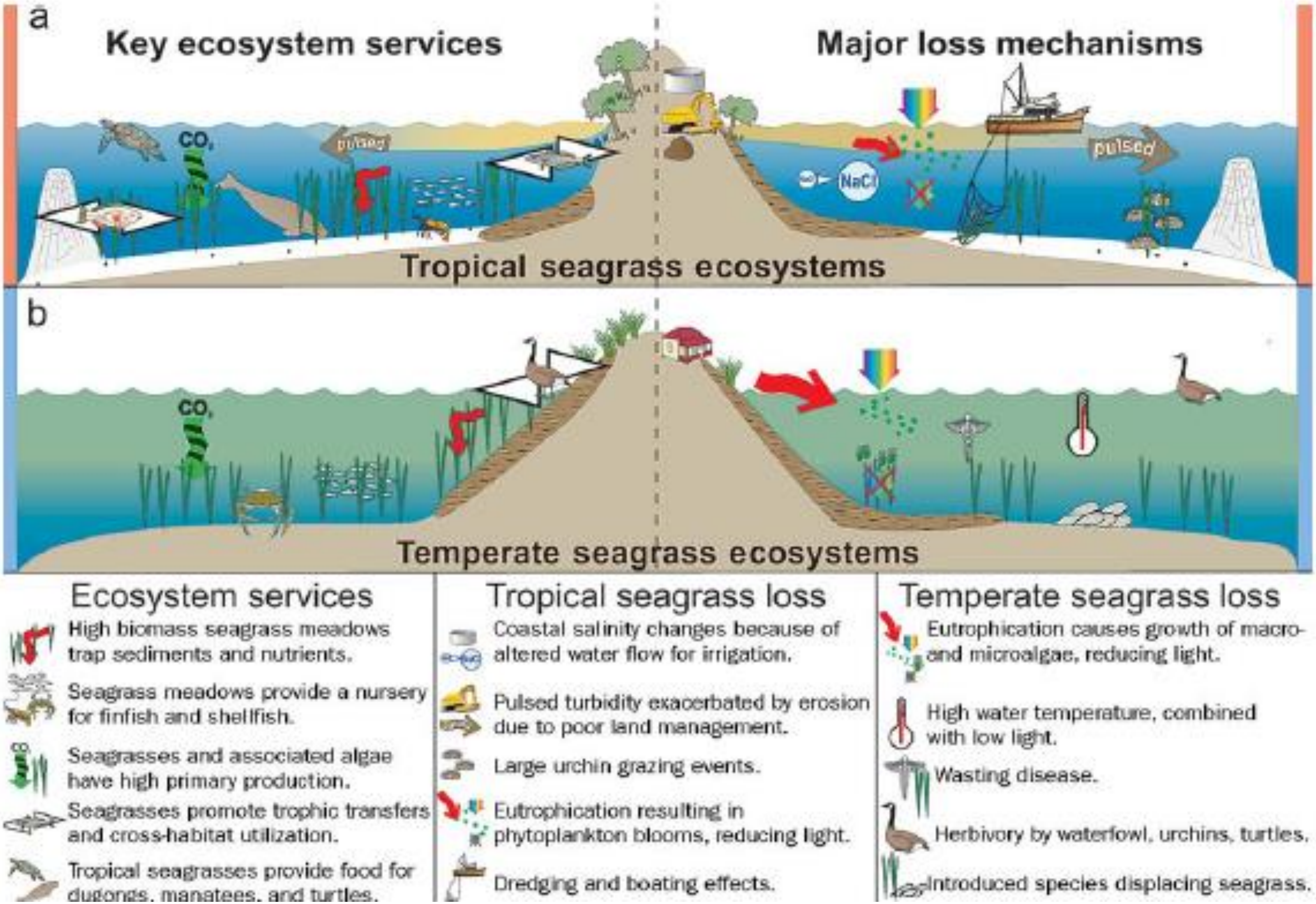


Figure 7–10

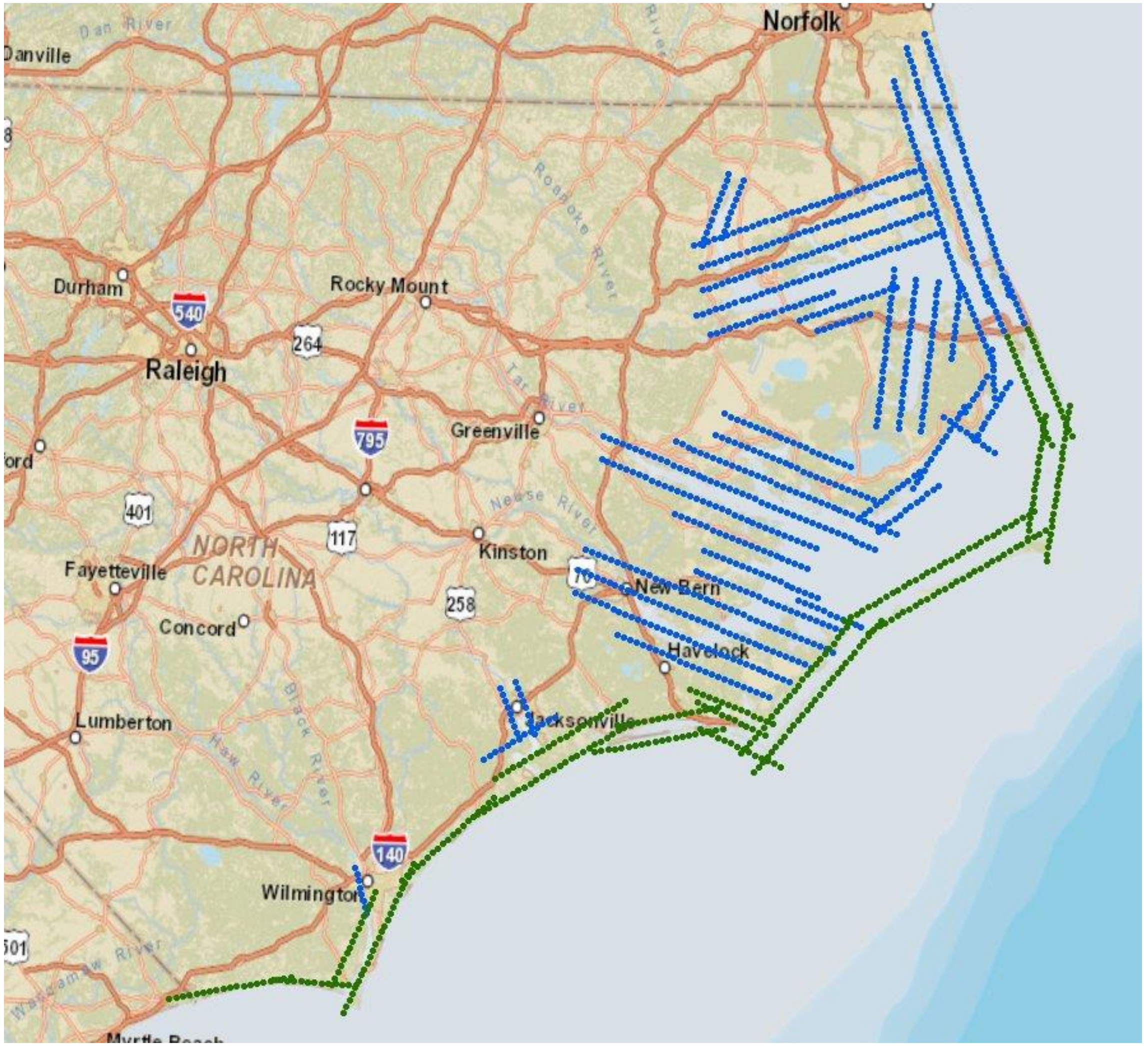
Seagrass Anatomy. The stems of seagrasses are called *rhizomes;* they grow horizontally beneath the bottom sediments. Roots, short shoots, and leaves grow directly from the rhizomes. The leaves contain many air spaces that help make them buoyant and that function in gas exchange. The flowers of seagrasses are small, white, and inconspicuous.

High-salinity species	Photos
Halodule wrightii (Shoal grass) Photo by: P. Prado	
Ruppia maritima (Widgeon grass) Photo by: P. Prado	
Zostera marina (Saltwater Eelgrass) Photo by: P. Prado	

Low-salinity species	Photos	Low-salinity species	Photos
Ceratophyllum demersum (Coontail) Photo by: W. Wellner		*Potamogeton perfolatus* (Redhead grass) Photo by: C.S. Krahforst	
Hydrilla verticillata (Hydrilla) Photo by: Wisconsin Dept. of Natural Resources		*Ruppia maritima* (Wideon grass) Photo by: C.S. Krahforst	
Myriophyllum spicatum (Eurasian watermilfoil) Photo by: C.S. Krahforst		*Stuckenia pectinata* (Sago pondweed) Photo by: K. Peters	
Najas quadalupensis (Busy pondweed) Photo by: wesserpest.com		*Vallisneria americana* (Wild celery) Photo by: C.S. Krahforst	
Potamogeton crispus (Curly-leaf pondweed) Photo by: P. Ferrari		*Zannichellia palustris* (Horned pondweed) Photo by: C.S. Krahforst	

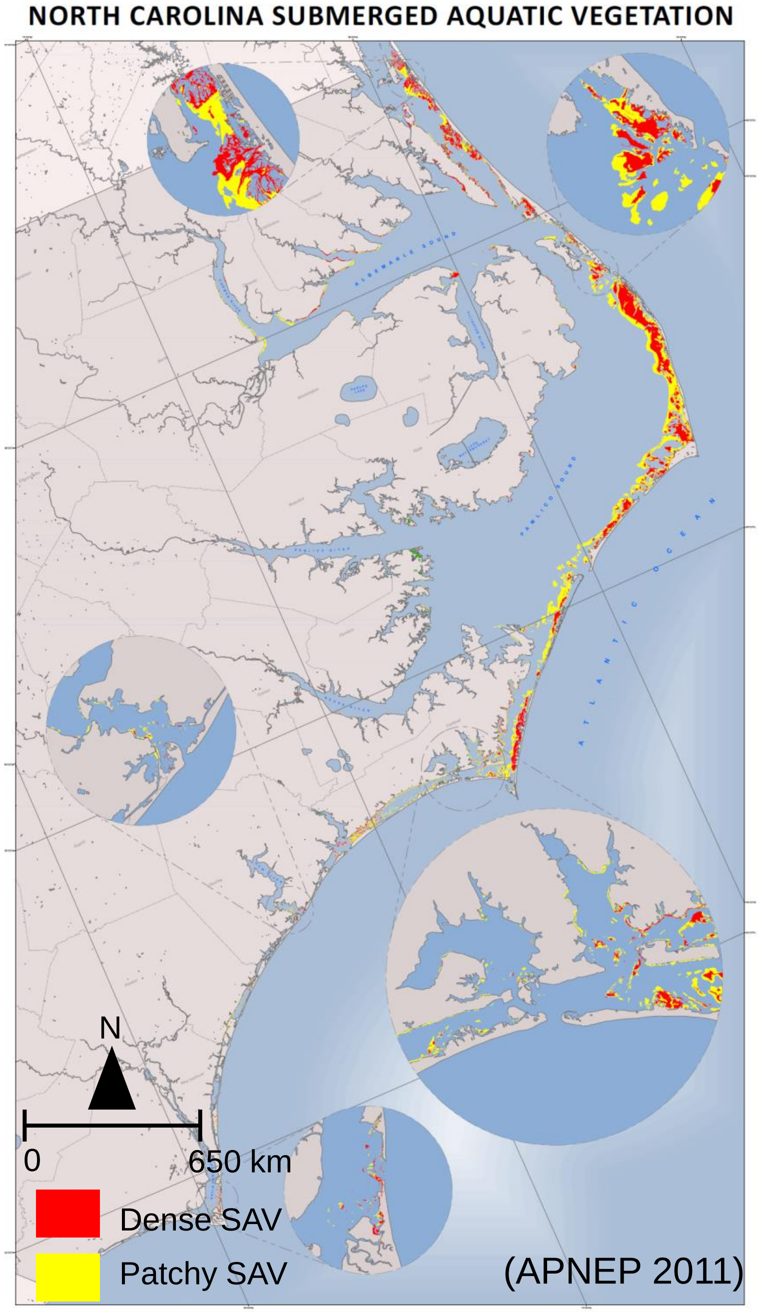

a
Key ecosystem services
Major loss mechanisms
CO2
pulsed
pulsed
NaCl
Tropical seagrass ecosystems
b
CO2
Temperate seagrass ecosystems
Ecosystem services
High biomass seagrass meadows trap sediments and nutrients.
Seagrass meadows provide a nursery for finfish and shellfish.
Seagrasses and associated algae have high primary production.
Seagrasses promote trophic transfers and cross-habitat utilization.
Tropical seagrasses provide food for dugongs, manatees, and turtles.
Tropical seagrass loss
Coastal salinity changes because of altered water flow for irrigation.
Pulsed turbidity exacerbated by erosion due to poor land management.
Large urchin grazing events.
Eutrophication resulting in phytoplankton blooms, reducing light.
Dredging and boating effects.
Temperate seagrass loss
Eutrophication causes growth of macro- and microalgae, reducing light.
High water temperature, combined with low light.
Wasting disease.
Herbivory by waterfowl, urchins, turtles.
Introduced species displacing seagrass.

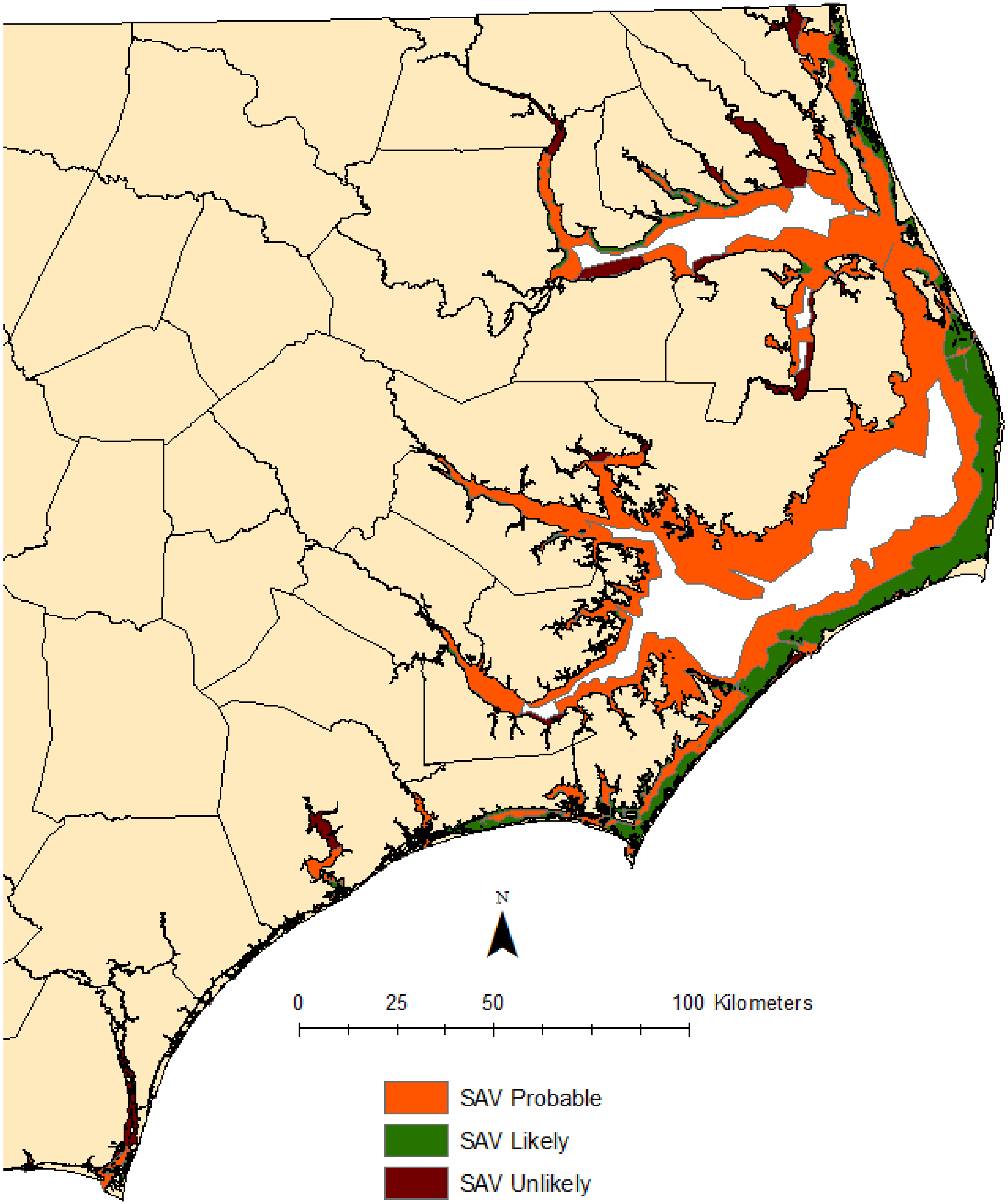
2007-2008 Digital Camera SAV Mapping



SAV in North Carolina

- The Albemarle-Pamlico Estuarine System (APES) is the 2nd largest estuarine system in U.S.
- 3rd largest area of SAV in the U.S.
  - 138,626 acres or 561 km^2
  - likely to be underestimated
- Challenges:
  - Aerial surveys only see in clear water (behind OBX)
  - Turbid regions must be surveyed on-the-ground ("invisible grass")
  - SAV is located in high and low salinity areas
  - SAV is highly seasonal
    - N. limit of *Halodule wrightii*
    - S. limit of *Zostera marina*




N
0
25
50
100 Kilometers
SAV Probable
SAV Likely
SAV Unlikely

	SAV Likely Shoreline (km)	SAV Probable Shoreline (km)	SAV Unlikely Shoreline (km)
Barrier Island Shelf	710.7 (66.6%)	357.0 (33.4%)	0 (0%)
Cape Fear	152.4 (4.6%)	1143.5 (34.3%)	2035.4 (61.1%)
Currituck	873.2 (60.0%)	305.1 (21.0%)	278.0 (19.0%)
Inner Banks	241.3 (20.8%)	917.8 (79.2%)	0 (0%)
Rivers	961.76 (16.7%)	2941.6 (51.0%)	1863.0 (32.3%)

% indicates the proportion of shoreline within the specified region within each category

	SAV Likely Shoreline (km)	SAV Probable Shoreline (km)	SAV Unlikely Shoreline (km)	Total Shoreline (km)
Barrier Island Shelf	710.7 (5.6%)	357.0 (2.8%)	0 (0%)	1067.7 (8.4%)
Cape Fear	152.4 (1.2%)	1143.5 (9.0%)	2035.4 (15.9%)	3331.23 (26.1%)
Currituck	873.2 (6.8%)	305.1 (2.4%)	278.0 (2.2%)	1456.3 (11.4%)
Inner Banks	241.3 (1.9%)	917.8 (7.2%)	0 (0%)	1159.1 (9.1%)
Rivers	961.76 (7.5%)	2941.6 (23.0%)	1863.0 (14.6%)	5766.4 (45.1%)
Total	2939.3 (23%)	**5664.9 (44.3%)**	4176.5 (32.7%)	12780.7 (100%)

% indicates the proportion of total shoreline

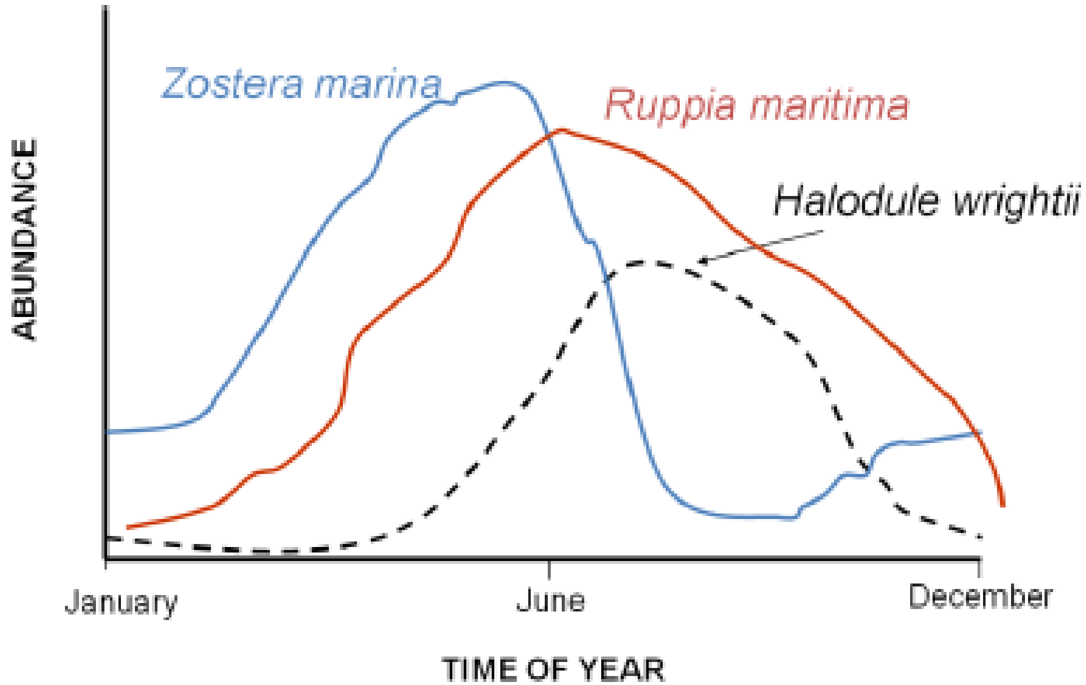
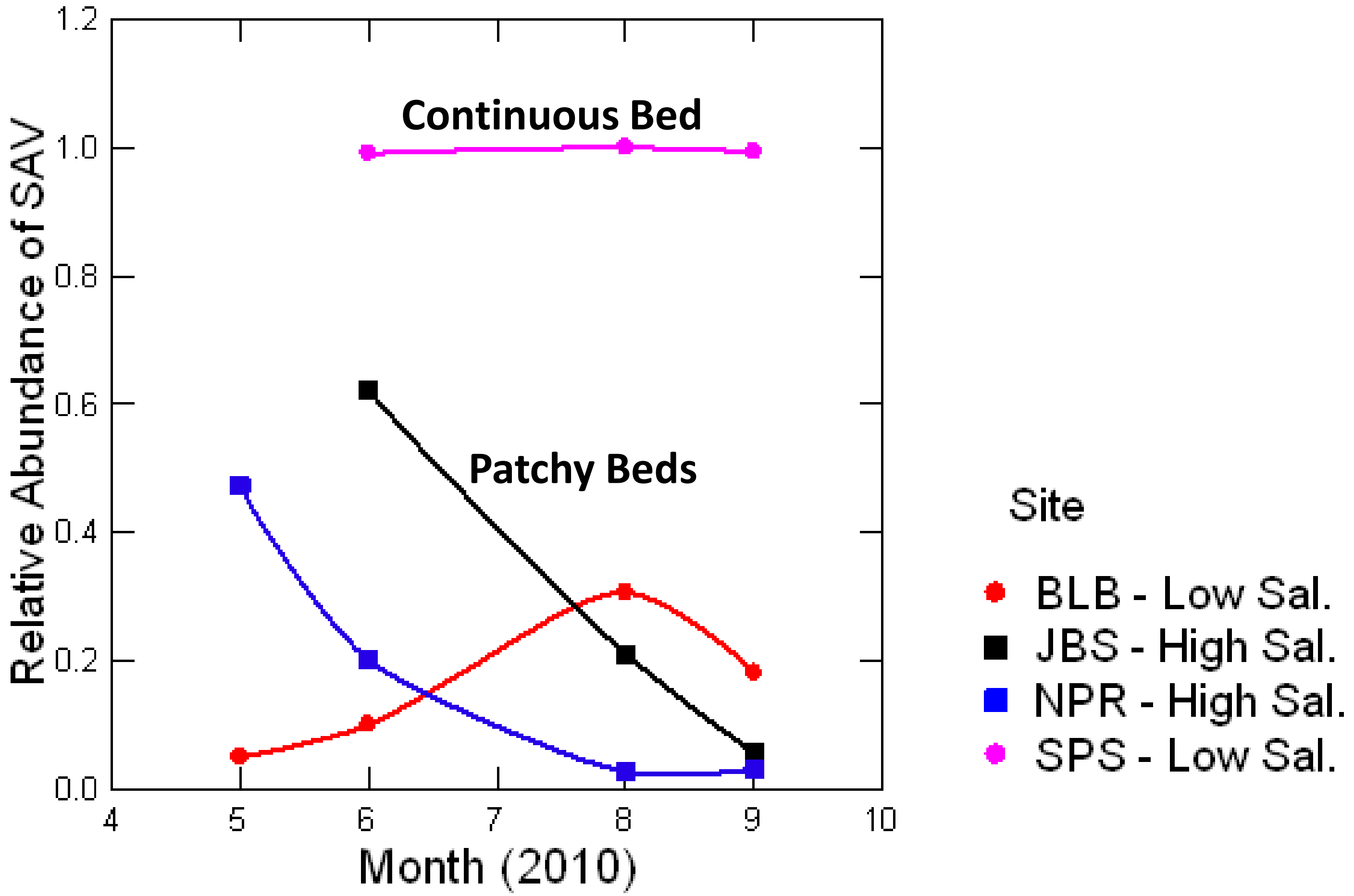


Figure 5. Abundance throughout the year of three seagrass species commonly found in high- salinity environments of North Carolina.

Seasonal Change in SAV Areas High and Low Salinity in 2010



APNEP Protocol for SAV Monitoring

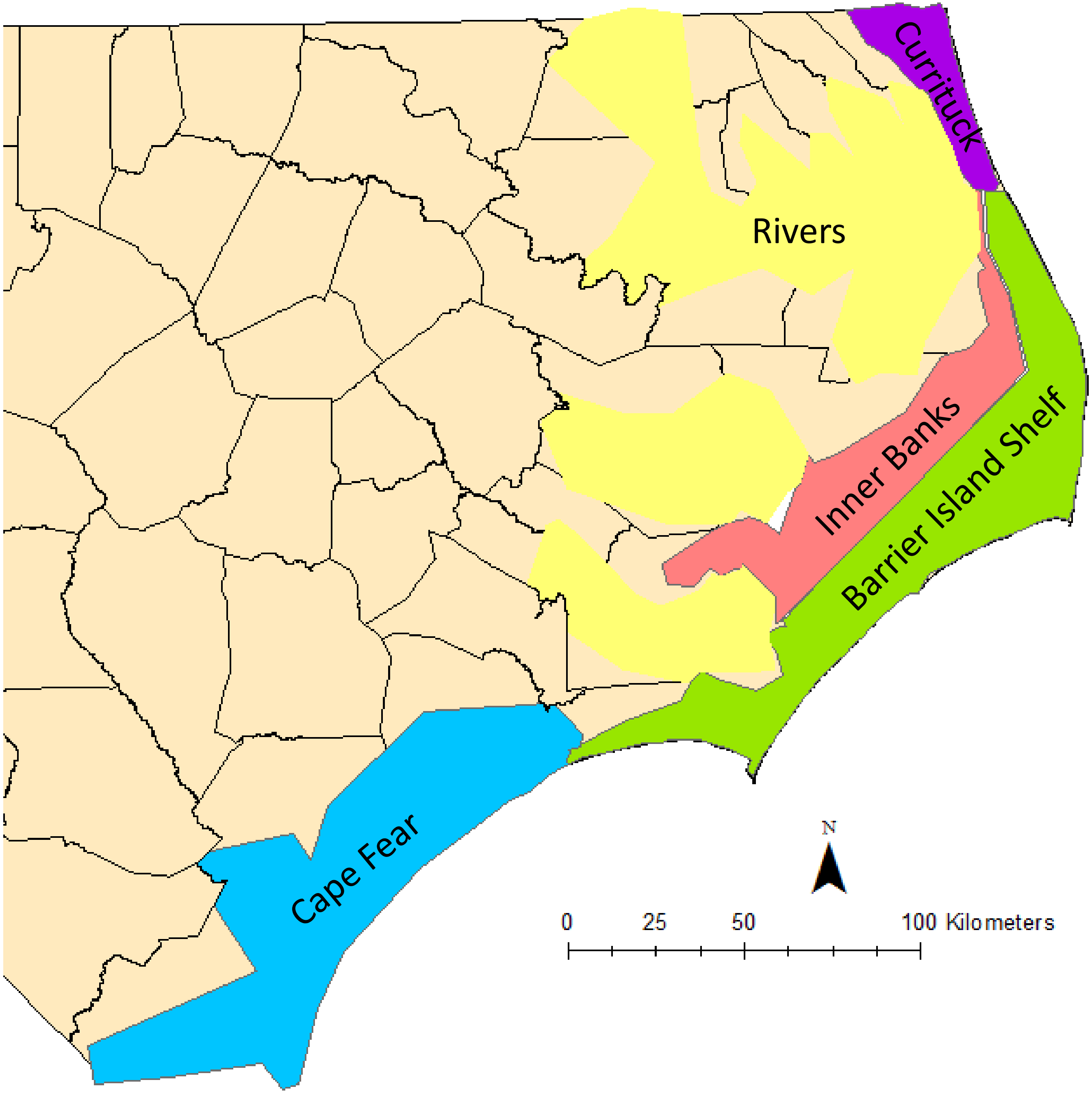
- Use multiple methods
  - Aerial digital imagery is best for shallow (≤ 1m) water environments
    - Large area of coverage
    - Problems with turbid areas, sun angle, and cloud cover
  - SONAR and video together can be used to ground truth digital imagery at water depths ≥ 1 m at sentinel sites

Kenworthy, J., C. Buckel, D. Carpenter, D. Eggleston, C. Krahforst , D. Field , J. Luczkovich , G. Plaia. 2012. **DEVELOPMENT OF SUBMERGED AQUATIC VEGETATION MONITORING PROTOCOLS IN NORTH CAROLINA. Final report to the CRFL program**

Recommendations from APNEP Protocols by Kenworthy et al. (2012)

- Five regions, with multiple sentinel sites/region
  - Barrier Islands (polyhaline 18-35 ppt)
  - Southern NC (polyhaline 18-35 ppt)
  - Rivers and sounds (oligohaline 0-10 ppt: Albemarle, Pamlico R., Neuse R.)
  - Currituck Sound (oligohaline 0-10 ppt)
  - Inner Banks (mesohaline 10-18 ppt)

Kenworthy, J., C. Buckel, D. Carpenter, D. Eggleston, C. Krahforst , D. Field , J. Luczkovich , G. Plaia. 2012. **DEVELOPMENT OF SUBMERGED AQUATIC VEGETATION MONITORING PROTOCOLS IN NORTH CAROLINA. Final report to the CRFL program**


Currituck
Rivers
Inner Banks
Barrier Island Shelf
Cape Fear
N
0
25
50
100 Kilometers

Research Questions

- SAV can be killed or coverage reduced by harmful algal blooms, phytoplankton blooms, nutrient pollution, sediment plumes, dredging events, propellers, pesticides, storms, climate change, and natural agents (birds, rays, manatees).
- How much does the SAV change from year-to year?
- Is it growing, shrinking, or staying the same?
- Areal coverage can be obtained from imagery and ground truth, but what is the variation?
- Probability estimates must be attached to the area estimates to understand a *significant* change.

Objectives

1) Test a sampling protocol for a long-term, in-the-water probabilistic based method to monitor the distribution and change in SAV habitat in coastal waters statewide, and evaluate the relationship between environmental conditions and SAV distribution.
2) Compare SAV cover data from echosounders and low-light underwater cameras to determine accuracy of SONAR for monitoring.

Methods - Sentinel Sites

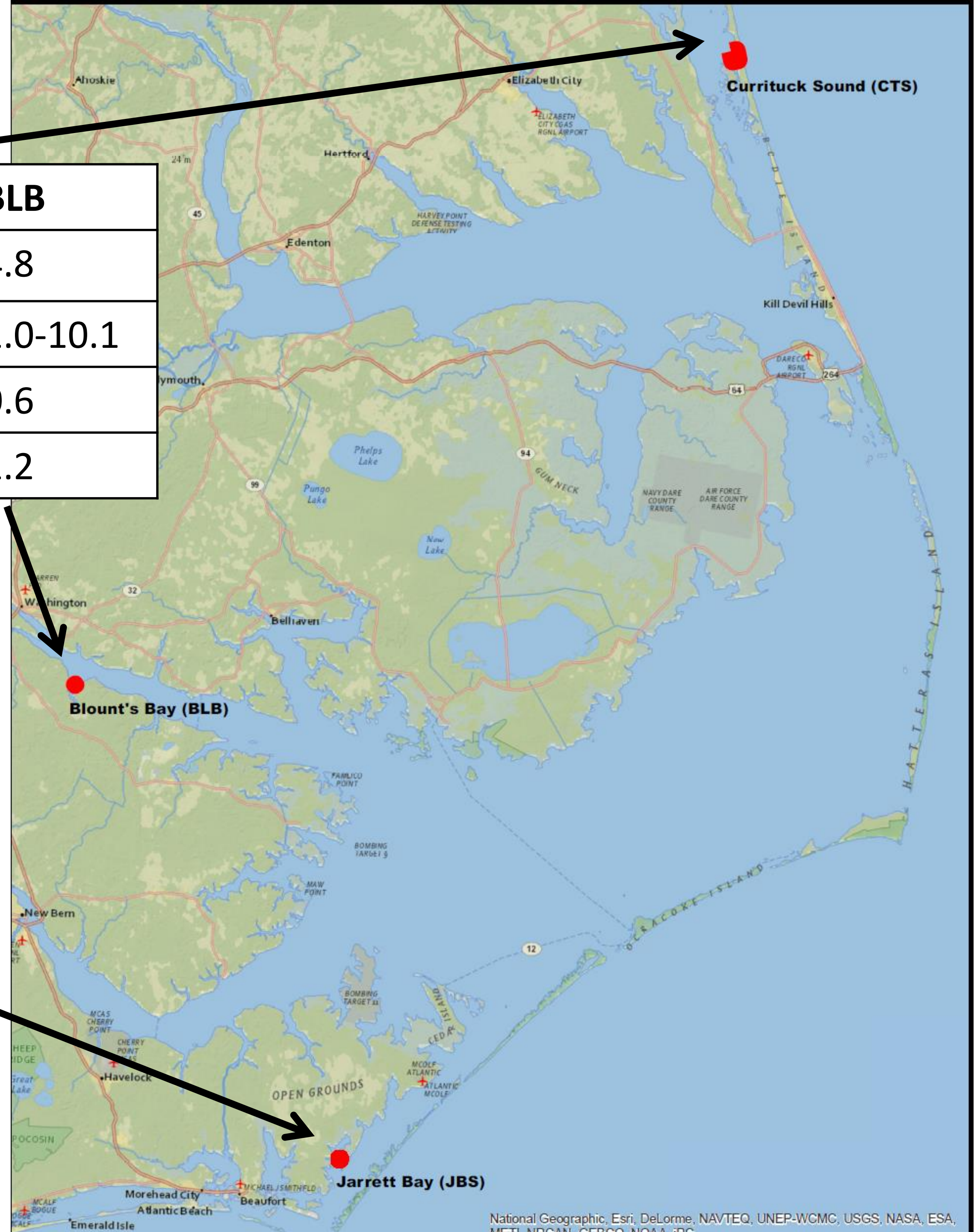
- Seagrass monitoring **APNEP protocol** was tested using DTX and Lowrance acoustic surveys and video surveys were conducted in Sep 2012 and May 2013 at three **Sentinel Sites** throughout the Albemarle-Pamlico Estuarine System.
- **Sentinel site** polygons selected for comparison with previous surveys (Kenworthy et al. 2012, and Luczkovich et al. 2010).
- One of the sites was **high-salinity** (>30 ppt): located at **Jarrett Bay** (JBS)
- Two of the sites were **low-salinity** (<10 ppt), one located at **Currituck Sound** (CTS) and the other at **Blount's Bay** (BLB).
- 30 – 90 shore-normal transects established across polygons at 10 m -25 m spacing.
- Video validation at 100 randomly selected points along transects.
- Compute a percent accuracy:

$$Accuracy\ \% = \frac{True\ Positive\ Points + True\ Negative\ Points}{Video\ Points} \times 100$$

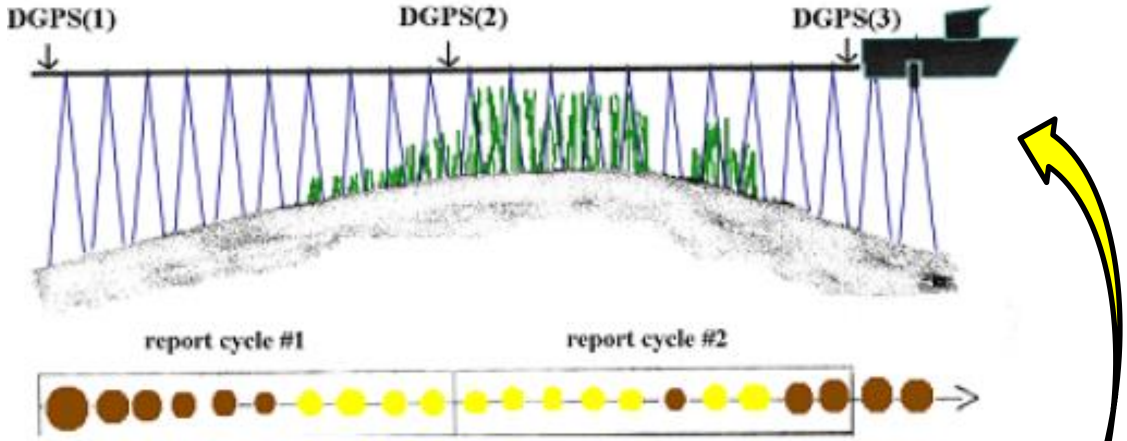
- Comparisons were made with 2010 surveys at the same sites and Quadrat sampling or video sampling along transects.

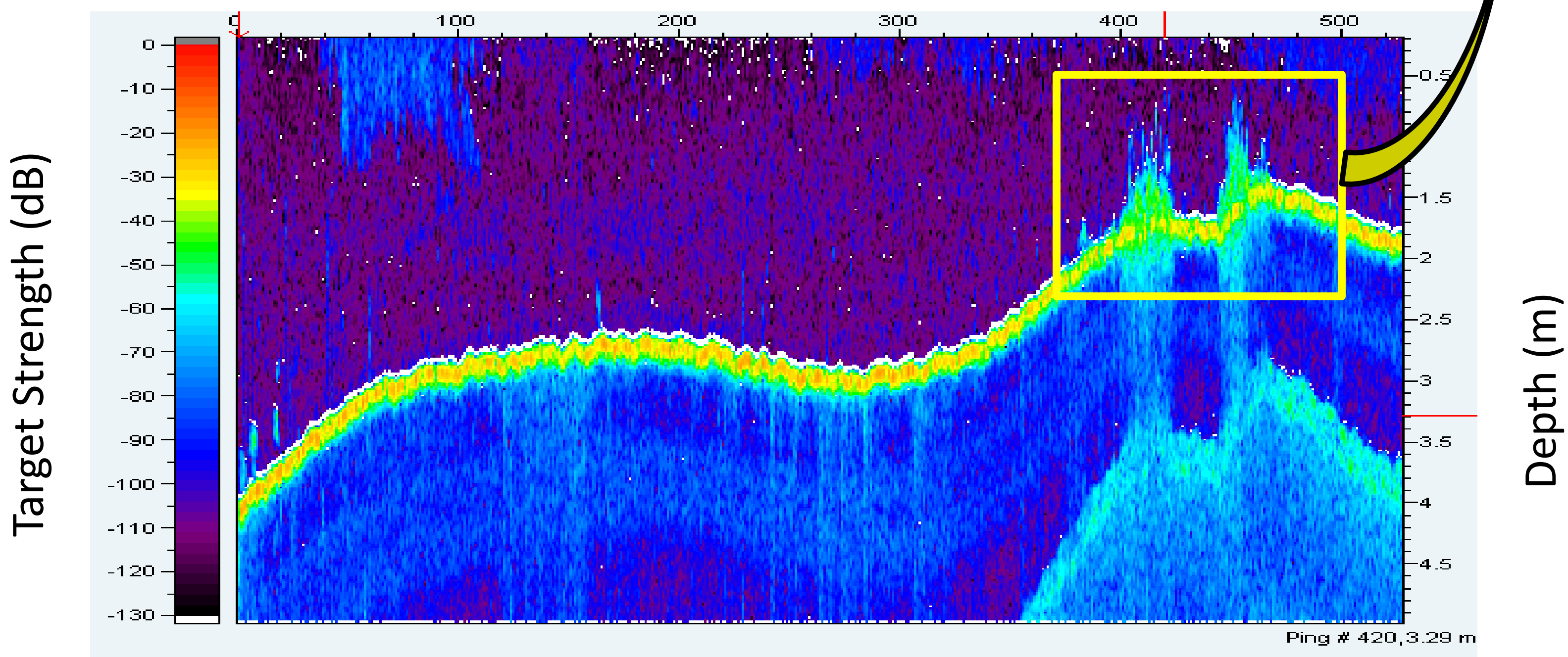
Low-Salinity Sites	**CTS**	**BLB**
Salinity (ppt)	3.4	4.8
Salinity range	2.9 - 3.8	2.0-10.1
Secchi Depth (m)	0.4	0.6
Average Depth (m)	1.5	1.2

High-Salinity Site	**JBS**
Salinity (ppt)	32.2
Salinity range	30.6-33.4
Secchi Depth (m)	0.8
Average Depth (m)	0.8



SONAR (BioSonics DTX & EcoSAV) Method

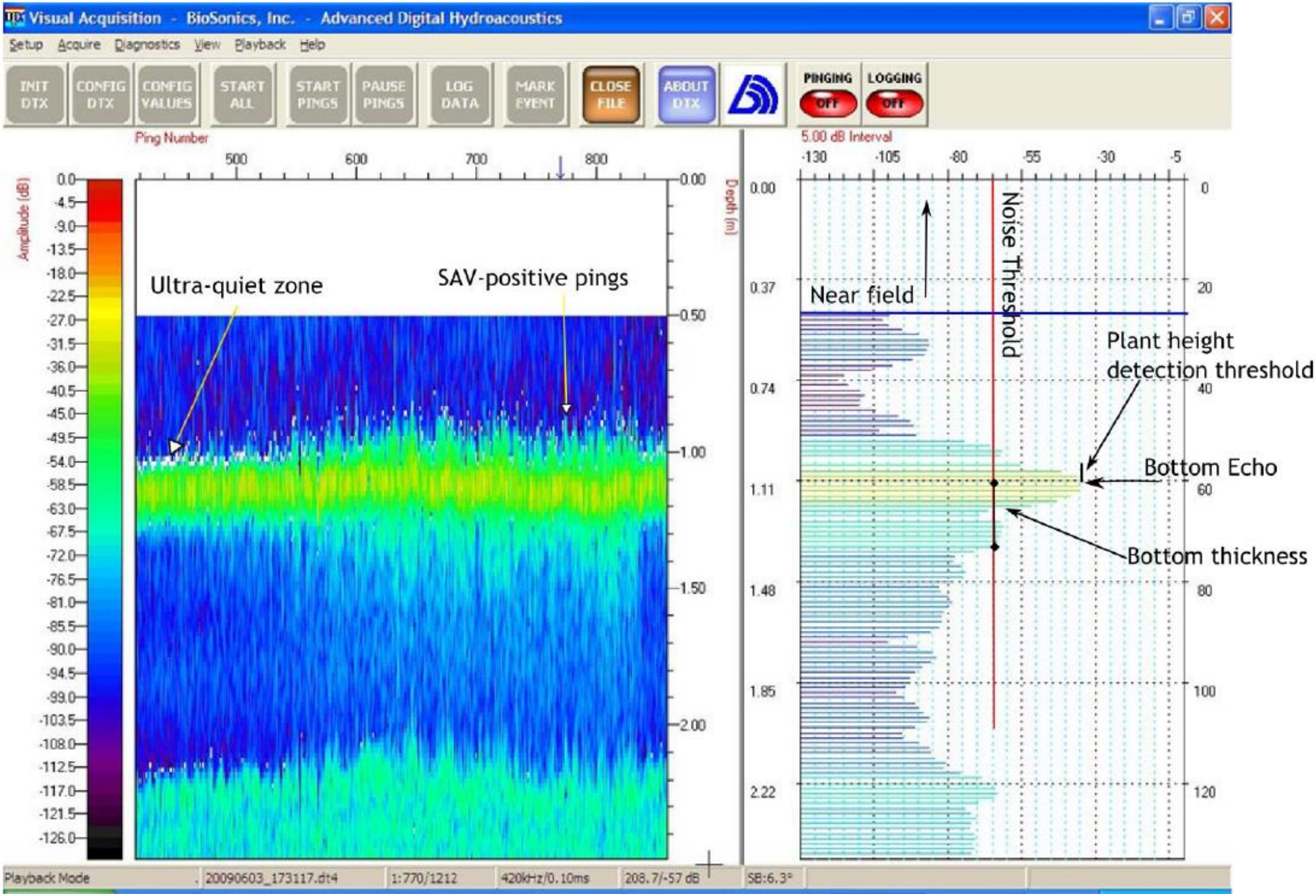




Scientific model, high cost $30,000

Lowrance HDS5 Echosounder and ciBioBase SAV Analysis

Consumer model, low cost: $700
ciBioBase – subscription costs $2,600/year



Visual Acquisition - BioSonics, Inc. - Advanced Digital Hydroacoustics
Setup Acquire Diagnostics View Playback Help
INIT DTX
CONFIG DTX
CONFIG VALUES
START ALL
START PINGS
PAUSE PINGS
LOG DATA
MARK EVENT
CLOSE FILE
ABOUT DTX
PINGING OFF
LOGGING OFF
Ping Number
Amplitude (dB)
Depth (m)
5.00 dB Interval
Ultra-quiet zone
SAV-positive pings
Near field
Noise Threshold
Plant height detection threshold
Bottom Echo
Bottom thickness
Playback Mode
20090603_173117.dt4
1:770/1212
420kHz/0.10ms
208.7/-57 dB
SB:6.3°

Video Method

- High-resolution low-light drop camera
- Camera fixed 13cm above bottom
- Frame size ~$0.25m^2$
- Individual frames classified for SAV presence/absence
- 100 random points along sonar transects

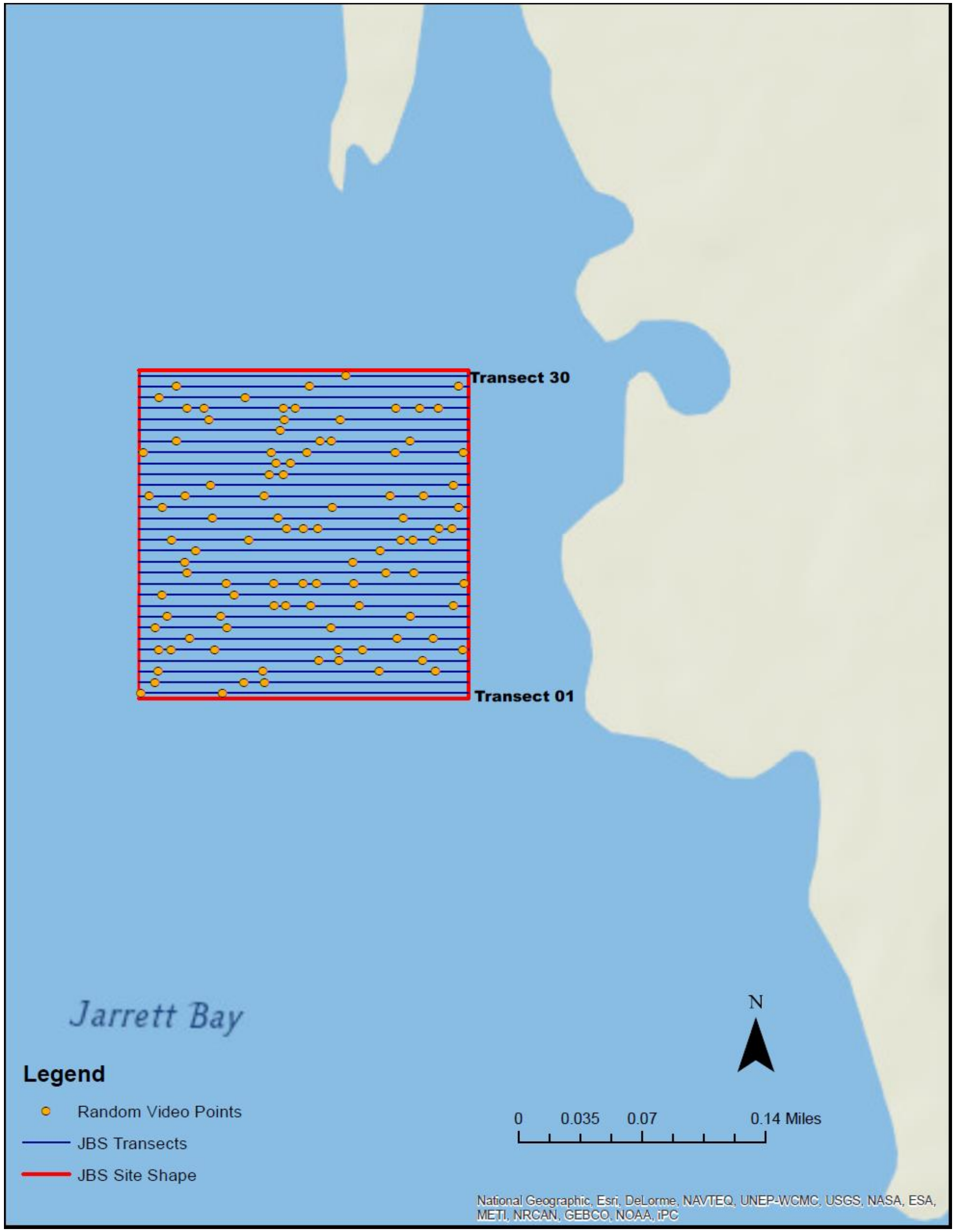
Left: Sample photo of *Vallisneria americana* (wild celery) as seen in Currituck Sound. Bottom: Still images of *V. americana* from videos showing SAV absent (left), sparse SAV presence (middle), and dense SAV presence (right).

Sonar and video APNEP Protocol

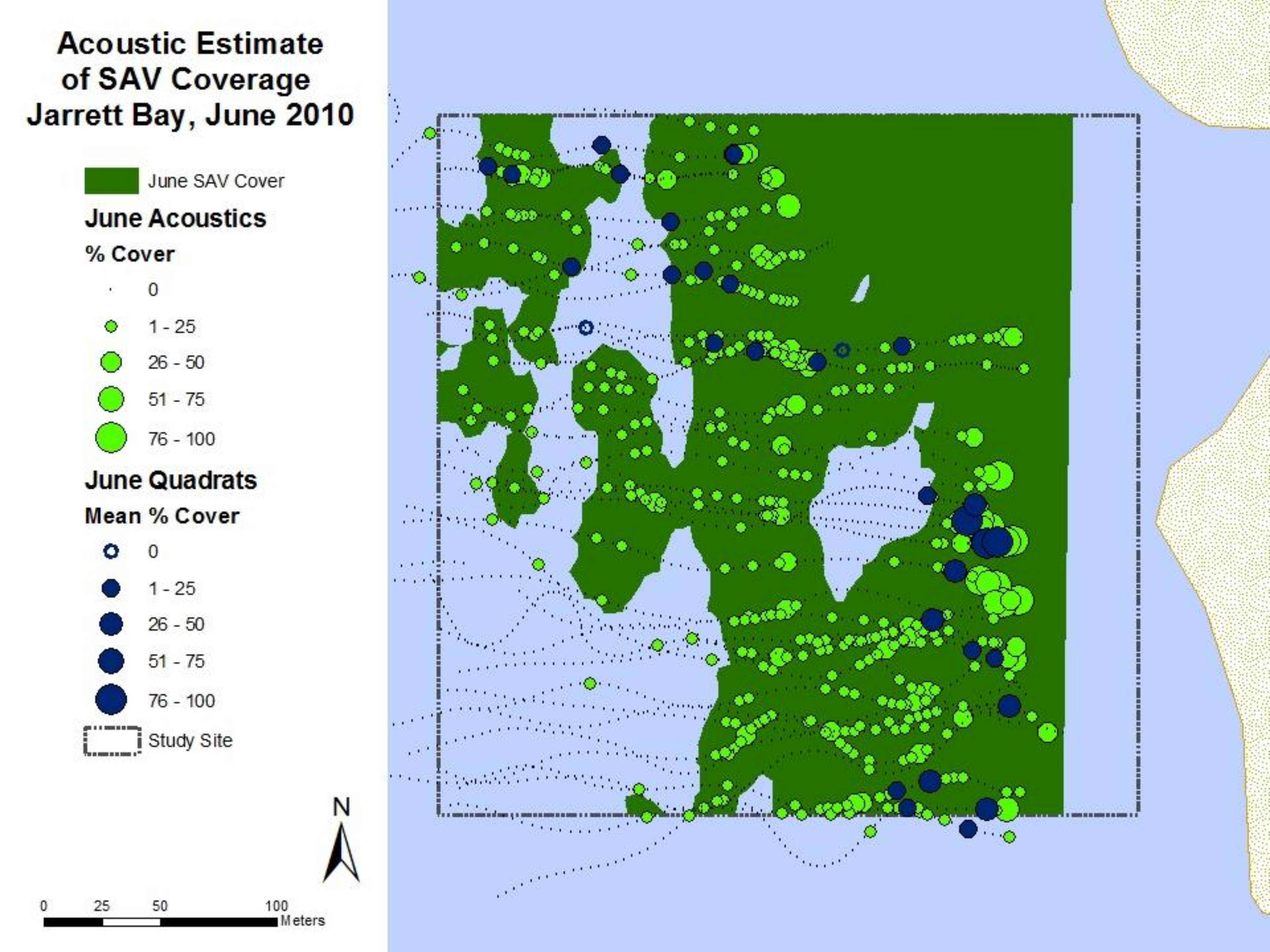
HIGH SALINITY AREAS

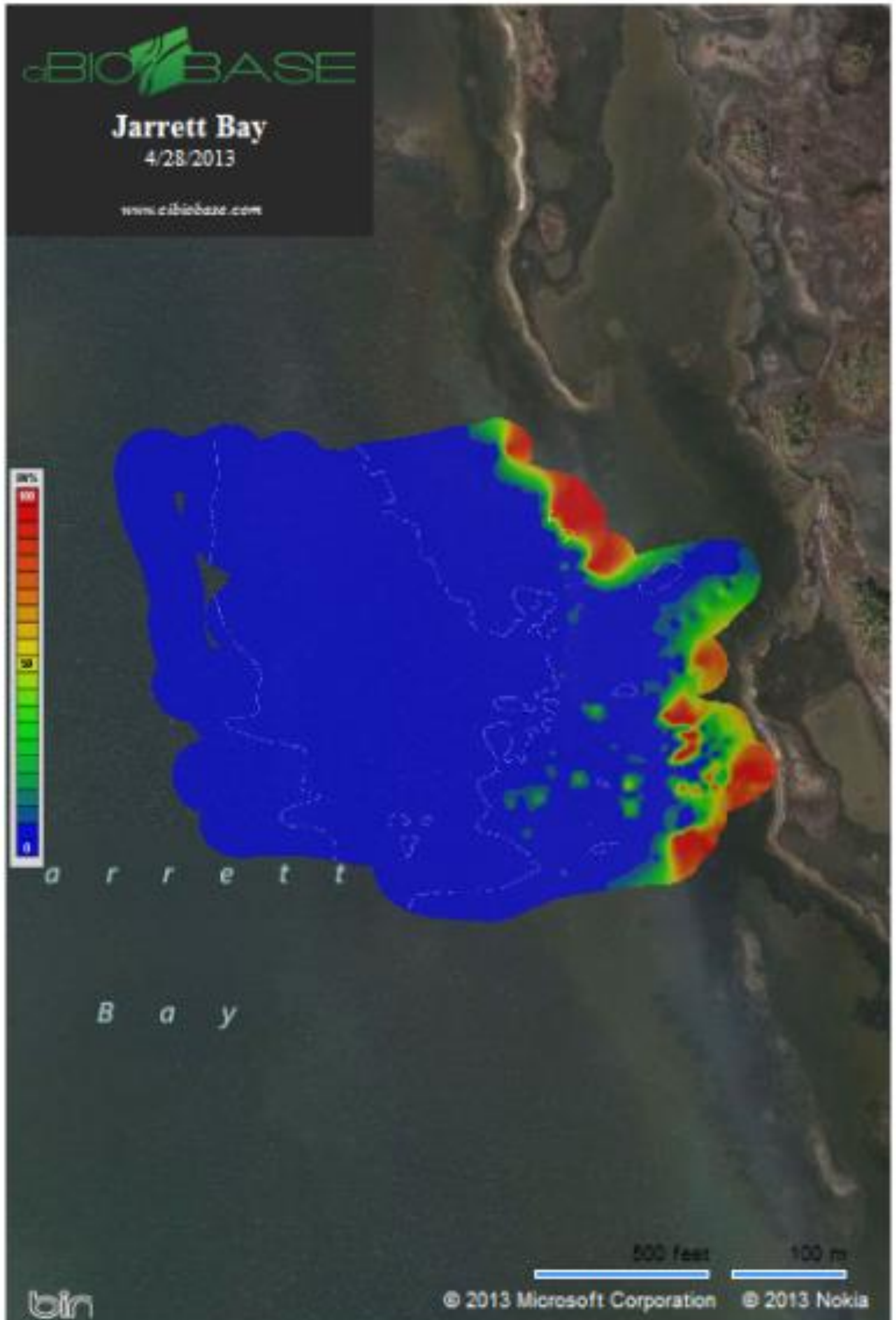
High-Salinity Sentinel Site

JARRETT BAY




WorldView-2 Image
September 2010
0
150
300
600
Meters
N


Acoustic Estimate
of SAV Coverage
Jarrett Bay, June 2010
June SAV Cover
June Acoustics
% Cover
0
1 - 25
26 - 50
51 - 75
76 - 100
June Quadrats
Mean % Cover
0
1 - 25
26 - 50
51 - 75
76 - 100
Study Site
N
0
25
50
100
Meters

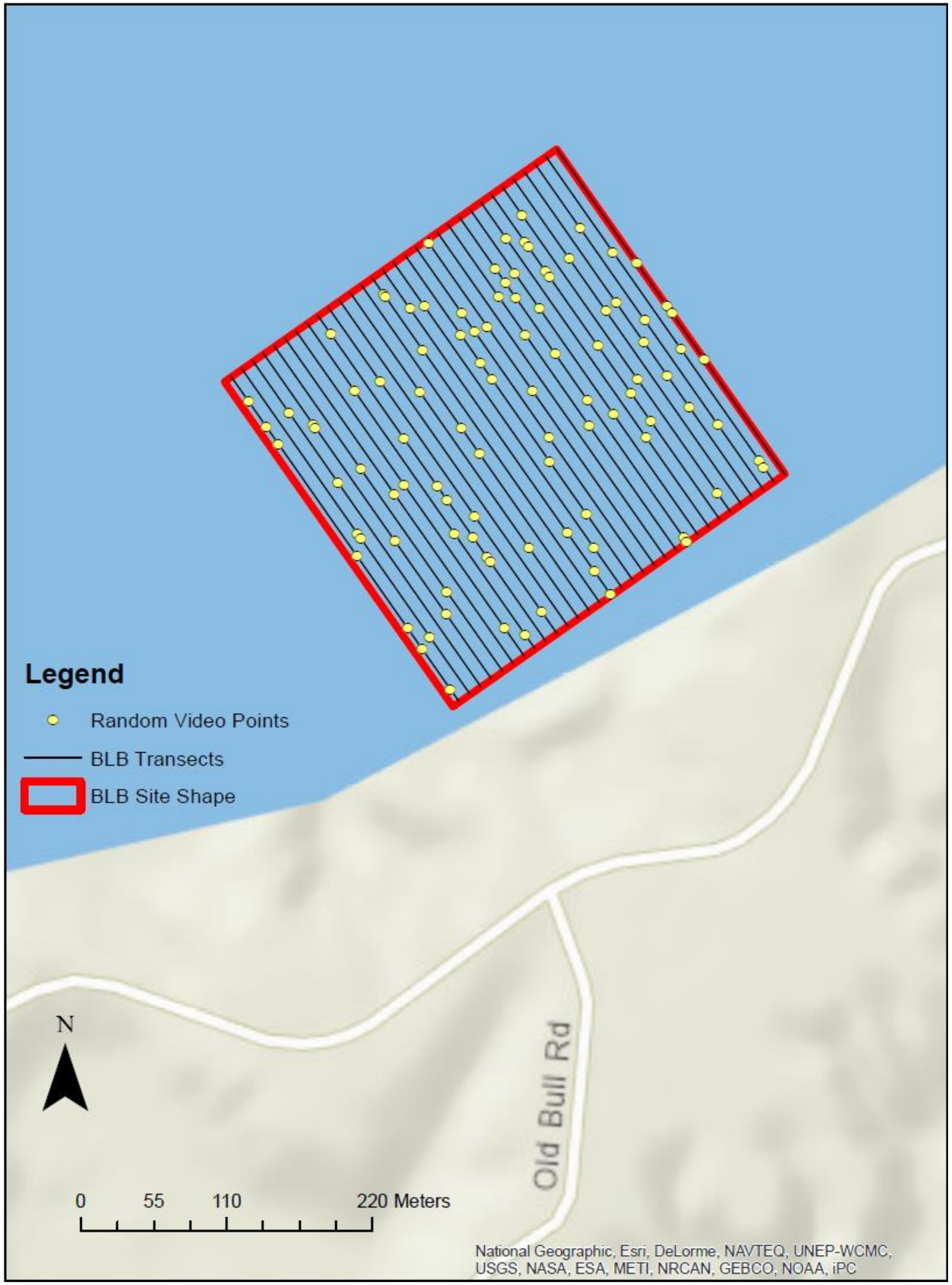

ciBIOBASE
Jarrett Bay
4/28/2013
www.cibiobase.com
100
50
0
arrett
Bay
500 feet
100 m
© 2013 Microsoft Corporation
© 2013 Nokia

Sonar, video, and quadrats

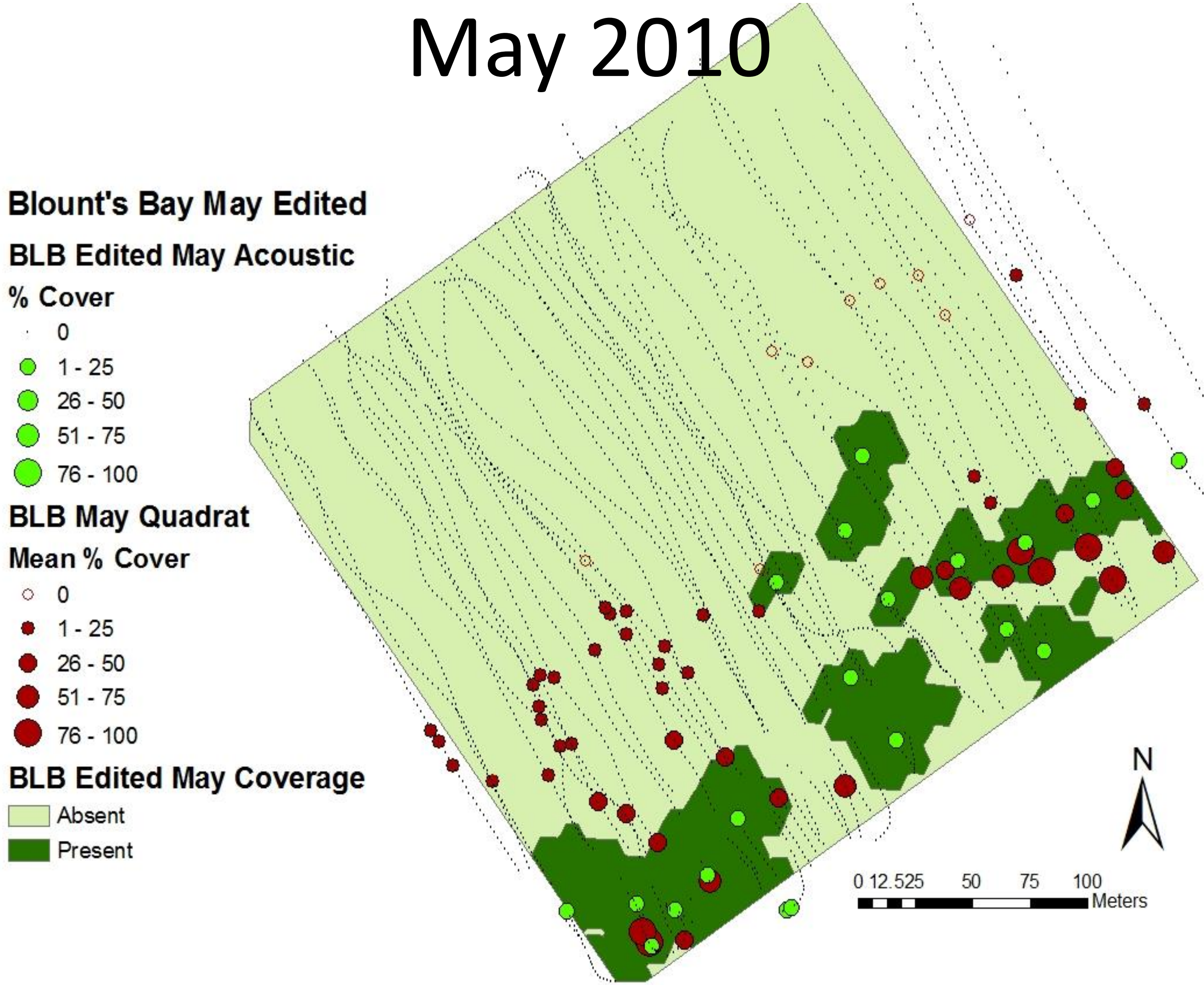
LOW SALINITY AREAS

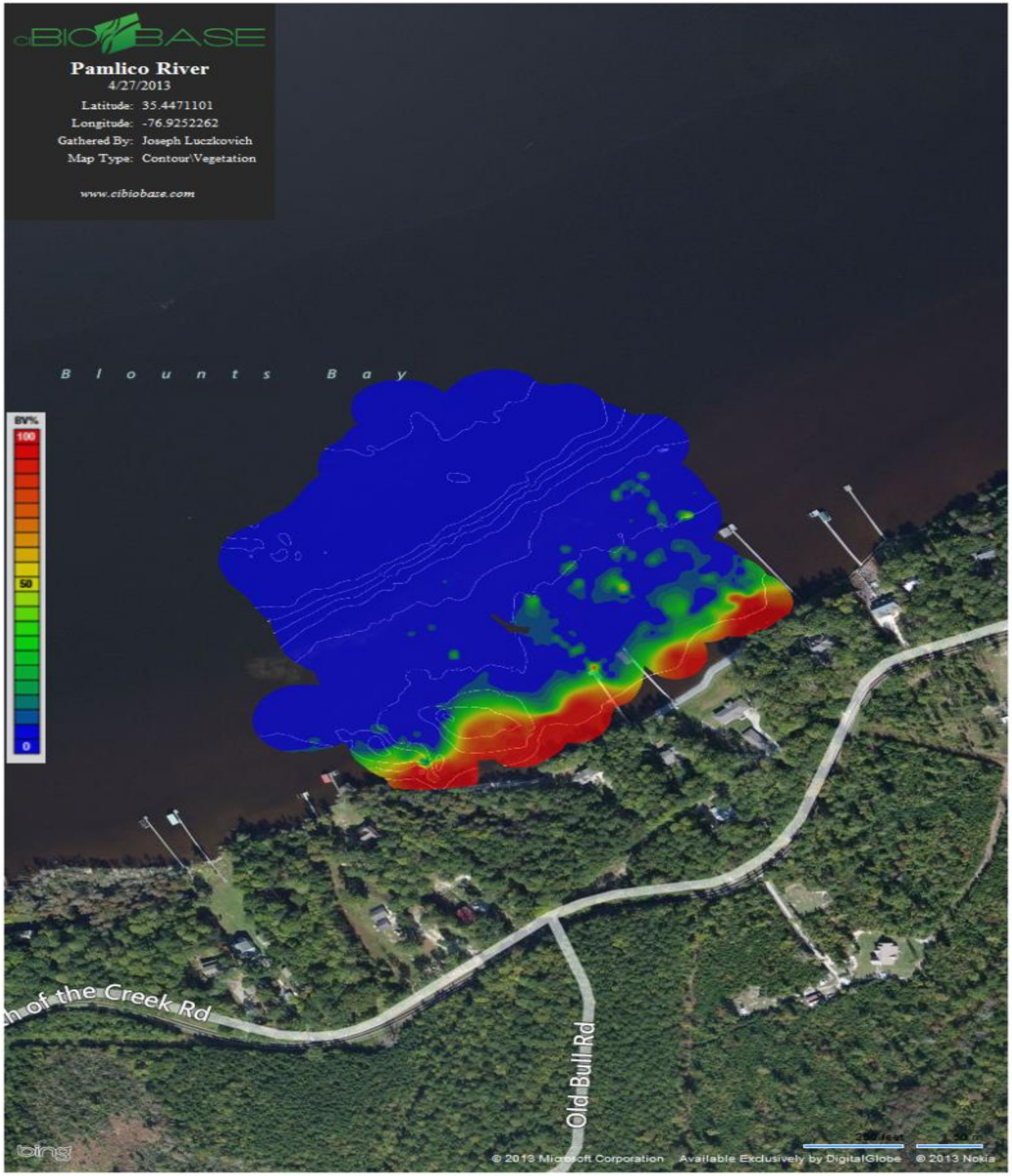
Low-Salinity Sentinel Site

BLOUNT’S BAY



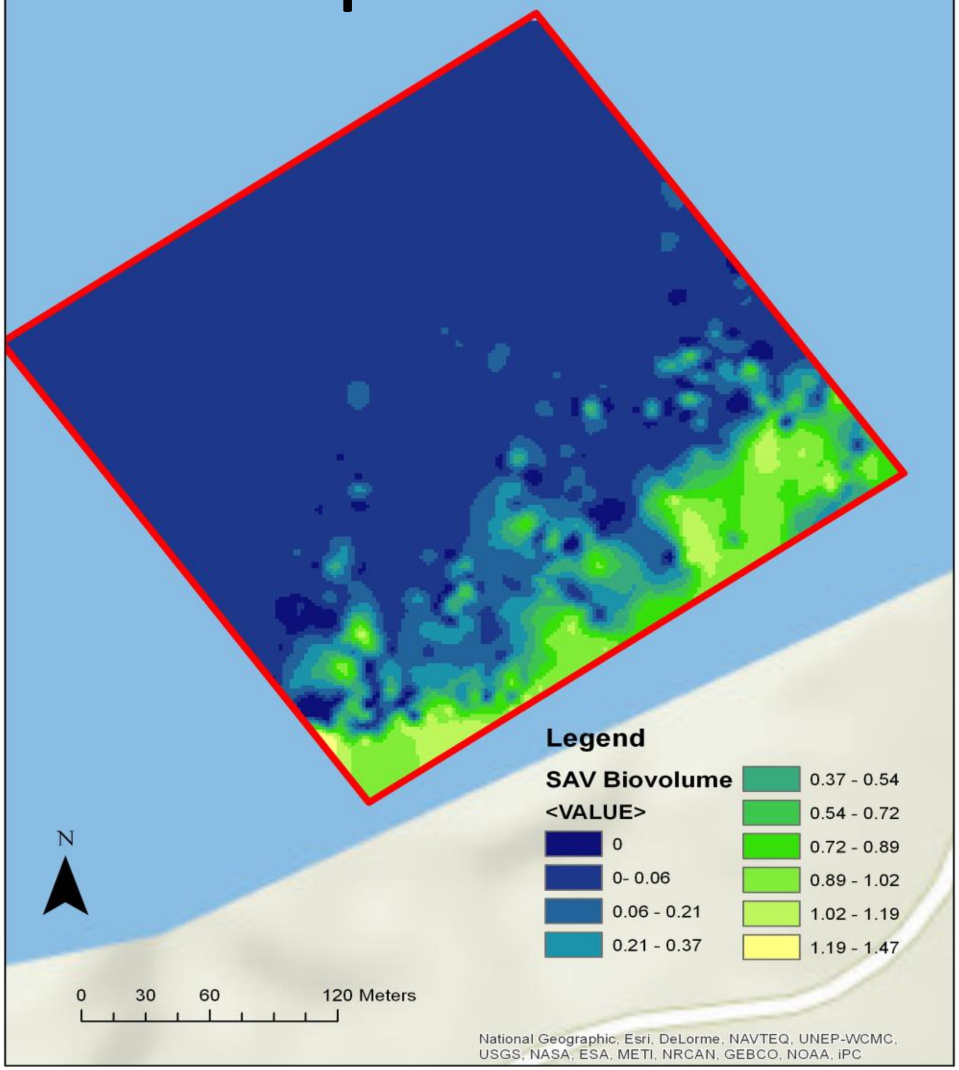
BioSonics DTX Echosounder May 2010





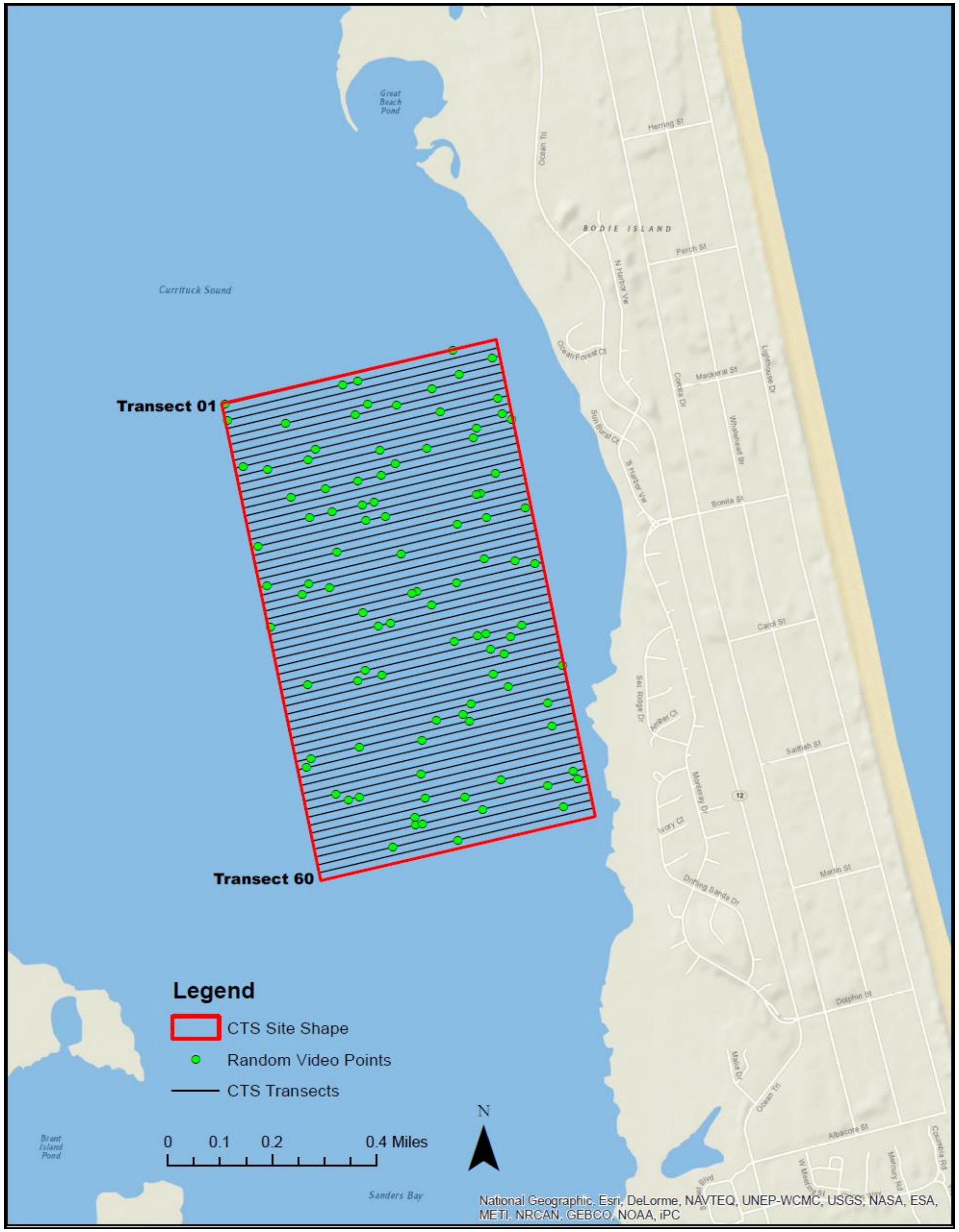
ciBIOBASE
Pamlico River
4/27/2013
Latitude: 35.4471101
Longitude: -76.9252262
Gathered By: Joseph Luczkovich
Map Type: Contour\Vegetation
www.cibiobase.com
Blounts Bay
BV%
100
50
0
th of the Creek Rd
Old Bull Rd
bing
© 2013 Microsoft Corporation Available Exclusively by DigitalGlobe © 2013 Nokia

Lowrance Echosounder Survey April 2013

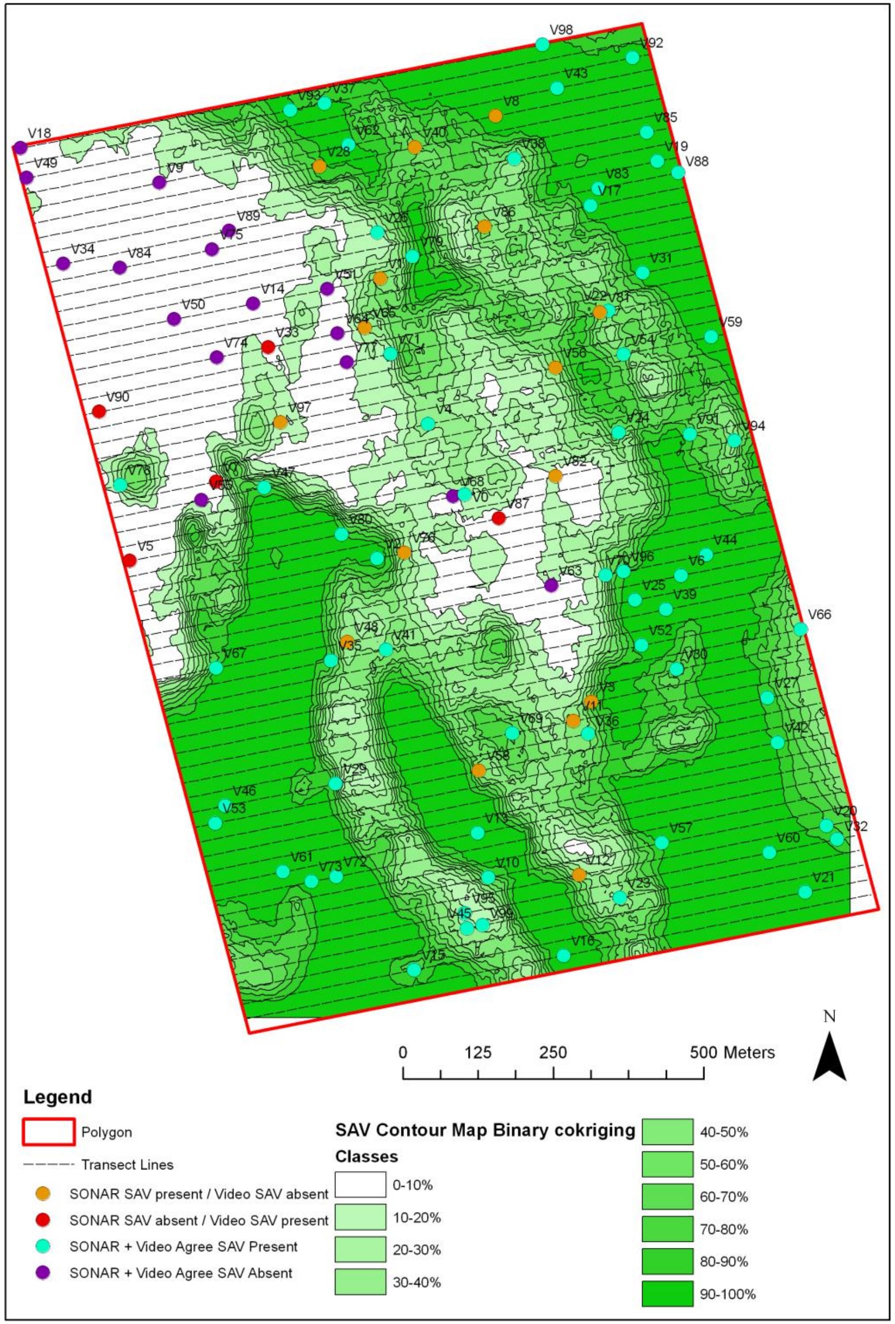


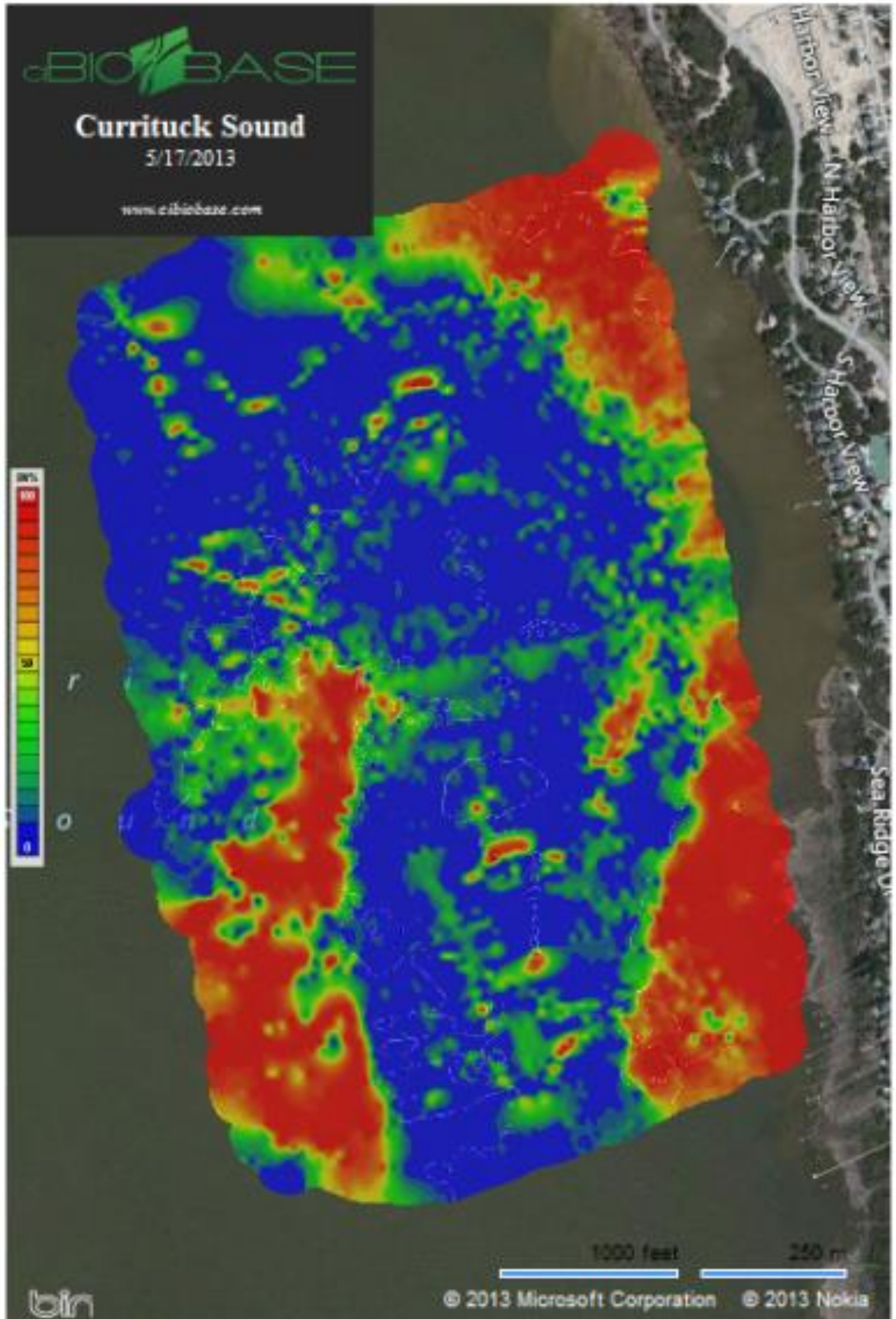
Low-Salinity Sentinel Site

CURRITUCK SOUND



CTS
September2012




BIOBASE
Currituck Sound
5/17/2013
www.cibiobase.com
100
50
0
Harbor View
N Harbor View
S Harbor View
Sea Ridge Dr
1000 feet
250 m
© 2013 Microsoft Corporation
© 2013 Nokia

Accuracy of SONAR versus Video

Sentinel Site	True Negatives Video - / SONAR -	True Positives Video + / SONAR +	False Positives Video - / SONAR +	False Negatives Video + / SONAR -	Not Classified	SONAR Video Agreed Points	Total Classified Points	Accuracy %
CTS	35	47	7	11	0	82	100	82
BLB	75	15	7	3	0	90	100	90
JBS	78	8	6	2	6	86	94	91.5

SAV Area Estimates

Sentinel Site	SAV area (m^2)	Total area (m^2)	SAV % cover
CTS May 2013	600,920	1,305,997	46.01%
BLB April 2013	20,727	91,792	22.6 %
BLB May 2010	2,248	91,761	2.4 %
JBS April 2013	14,923	90,180	16.6%
JBS June 2010	61,235	81,041	75.6%

SONAR Pros and Cons

- Cons of SONAR:
  - Water depth limit: > 0.8 m
  - SAV height limit: > 4 cm but does detect smaller
  - Can't tell species of SAV
  - Bottom type: mud, algae may give false positives
- Pros:
  - Fast (90,000 m^2 area with 48 transects, acquisition and analysis is do-able in 1 day)
  - Bathymetry is obtained simultaneously
  - Can estimate SAV change over a large area on a short (weeks/months) or long (years) time scale

Make new GIS Map for site selection

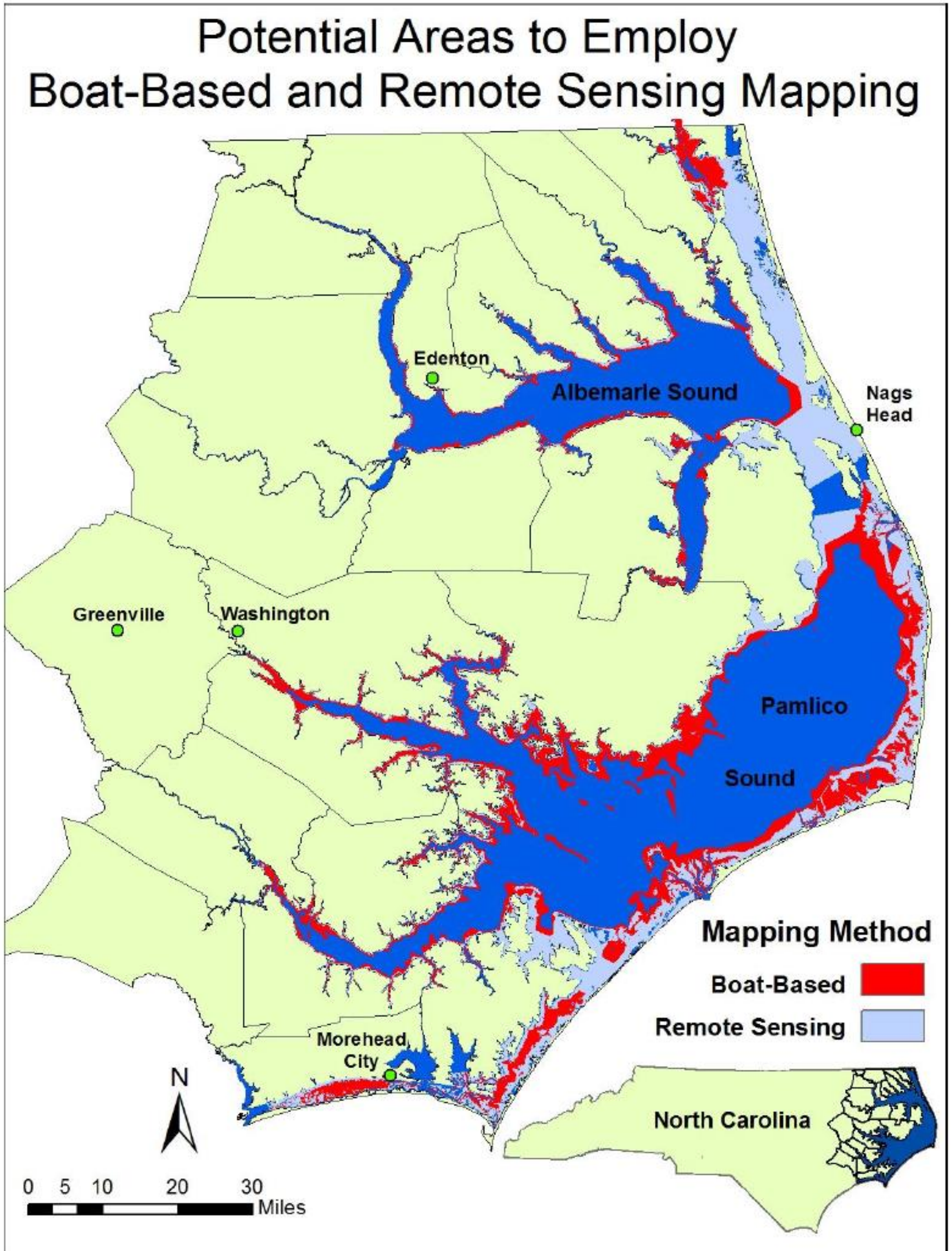
- Start with remote sensing accuracy assessment and bathymetry
- Depth < 0.8m is do-able by optical remote sensing (Digital Mapping Camera)
- Depths > 0.8 m must be visited by boat using acoustic surveys and video or diver quadrat surveys
- Acoustics survey with 30 transects/300 m (10 m spacing)
- Video drop camera at 100 randomly selected points

Boat-based SAV surveys
Min = 0.8 m
Max = 2.0 m

SONAR had 90% accuracy in depth
< 0.8 m

Boats can't easily work in < 0.8 m (true for video and acoustic methods); use wading or snorkeling and quadrat method

Choose more sentinel sites from red areas
Recommend > 25 sites



Cost Estimates from Kenworthy et al. (2012)	Cost
Underwater videography	
Underwater camera	$ 1,525
Video recording unit and Horita	$ 1,400
GPS (basic - differential)	$300 – 10,000
SONAR	
Equipment (echosounder, GPS, transducer, computer, cables)	$27,717
ECOSAV2 software	$ 3,000
Lowrance system & ci BioBase Analysis Subscription	$ 700 + $2,600 annual fee
Quadrats	
Equipment (PVS pipe, glue, PVC elbows, string) for ten 1 x 1 m quadrats with 100 cells	$130
GPS (basic)	$300
Snorkeling gear (snorkel, fins, mask, wetsuit) per person	$500
Remote Sensing	
Imagery	$350,000
Interpretation	$150,000
"Ground-Truthing"	$ 75,000

Cost estimates

- Cost for Remote sensing imagery $575,000
- Cost for 25 Sentinel Sites: ~ $40,000
  - 2 days per Sentinel Site (50 days for 25 sites)
  - Video verification: 1 day, 2 person crew
    - Camera, video deck & GPS - $ 3,225*
  - Acoustic: 1 day, 2 person crew
    - $700 Lowrance system *+ $2,600 subscription fee
    - $23000 DTX system + ECOSAV = $30,717*

* Equipment costs are largely a one-time initial investment with additional costs for maintenance. These expenses and those of a more perpetual nature such as video tapes, SD cards, data backup equipment, truck/vessel fuel, and travel costs will need to be considered in an overall cost estimate. The perpetual costs were not itemized here as they may not be relevant and can vary widely by organization.

Future SAV studies

1) Expand the sentinel sites to at least 25 sites in low and high salinity regions visited once every 5 years
2) Incorporate an outreach effort to disseminate information and educate and inform resource managers and the public on the value and status of SAV and the critical role of monitoring and conserving SAV habitat.
3) **Citizen science**: Recruit fishers and boaters to study SAV with their own echosounders (relatively cheap)
4) People should know the value SAV (at least $12,000 per acre in ecosystem services are provided by SAV).
5) SAV is worth about **$1.66 billion** in NC!

Thank You!

Coastal Recreational Fishing License Fund

Dean Carpenter, APNEP
Jud Kenworthy, NOAA
Dave Eggleston, NCSU
Christine Buckel, NOAA
Gayle Plaia, NCSU
Don Field, NOAA
Cecilia S. Krahforst, ECU
Rich Curran, ECU
Audrey Pleva, ECU
Chris Lanier