BENTHIC HABITAT CHARACTERIZATION WITHIN THE NEARSHORE OF MOBJACK BAY, VIRGINIA

Final Report to NOAA/ NOAA Chesapeake Bay Office

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FINAL REPORT

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Introduction

Estuarine habitat research and restoration efforts historically targeted a single habitat type, such as seagrass beds or saltmarshes. As such, little is known about how intertidal marshes and adjacent subtidal vegetated and unvegetated habitats interact and function together (Rozas and Odum 1987; Hettler 1989). However, there is a growing body of work that indicates the spatial arrangement and heterogeneity of habitats may have significant influence on biotic community interactions, such as foraging behavior, predation, competition as well as recruitment (Coen et al. 1981; Mittelbach 1986; Werner and Hall 1988; Danielson 1991; Irlandi and Crawford 1997; Micheli and Peterson 1999).

The cumulative impact of shoreline armoring has been demonstrated to drastically reduce available intertidal and subtidal habitat structure and associated fish communities (Beauchamp et al. 1994; Jennings et al. 1999; Bilkovic et al. 2005, Bilkovic and Roggero 2008). Throughout the coastal plain of Virginia, the conversion of natural shoreline to stabilization structures is occurring at a rapid pace. Understanding the functional roles of linkages between habitats and their influence on estuarine organisms is essential as efforts to manage estuarine systems and shoreline development evolve towards an ecosystem approach. In the Chesapeake Bay, there is currently no comprehensive assessment of aquatic habitat heterogeneity or understanding of the effects of multiple stressors on the viability of these habitats.

Mobjack Bay and its associated tributaries historically contained a diverse array of critical habitat types including oyster reefs, seagrass beds and tidal wetlands. Currently, multiple restoration efforts are underway throughout this watershed to mitigate losses from disease, and habitat destruction and modification (Figure 1). As a step in determining if specific habitats in combination are associated with fish communities descriptors, we collected detailed information on the quantity and distribution of nearshore subtidal habitat within Mobjack Bay Watershed. The result was the delineation of important Chesapeake Bay habitats for tributaries containing a variety of habitat restoration and monitoring efforts, such as oyster reef placement and SAV plantings.

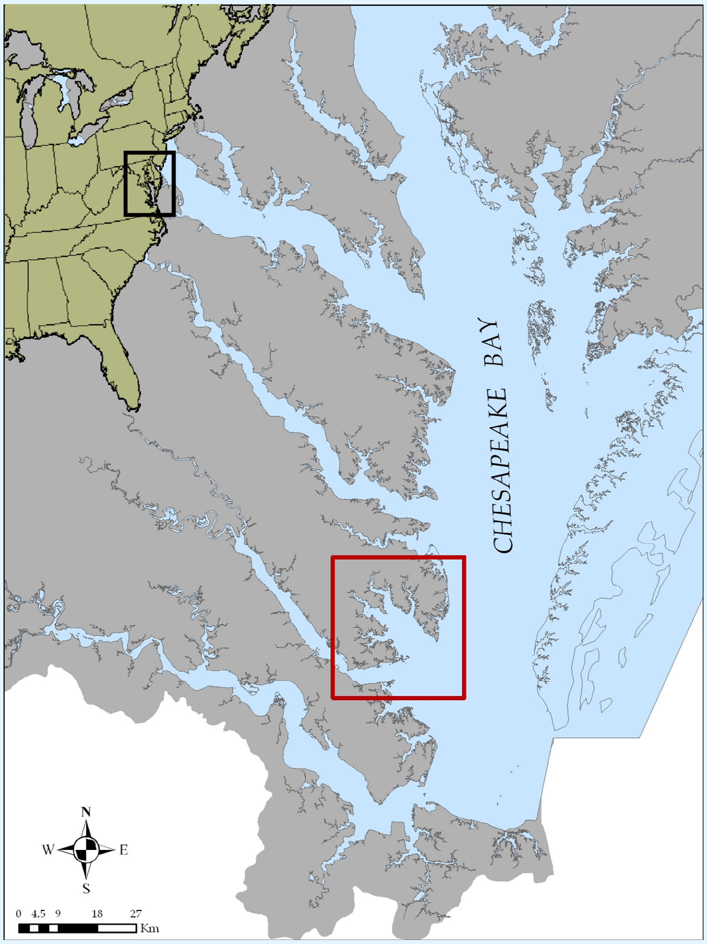


Figure 1. Location of the Mobjack Bay within the Chesapeake Bay in the Mid-Atlantic of the United States.

Project Objectives

To survey, map and quantify benthic habitat within the nearshore of Mobjack Bay, including the Severn, Ware, North and East Rivers using remote-sensing technologies. Final output includes digital geospatial characterization of the extent and distribution of prevalent nearshore habitats.

Methods and Results

Acoustic Surveys

Testing and calibration of equipment was completed prior to survey work to ensure the accuracy of data collected. Survey tracks were plotted based on the results of pilot surveys, which helped establish the most appropriate settings and protocols for the shallow-water habitat mapping of Mobjack Bay (Figure 1).

Benthic habitats between 1 and 4 meter depth were surveyed in four tributaries of the Mobjack Bay (Severn, Ware, North, East rivers) and select sections of the Bay proper during May through July 2007 with multiple acoustic technologies. Benthic characterization was completed with side-scan sonar technology (Sea Scan Marine Sonics, 600 kHz) and an echo-sounder (Knudsen 320 BP; Kel 28/200 kHz dual-frequency transducer). A Crescent R100 series Differential Global Positioning System (DGPS) receiver (accuracy sub-meter), in conjunction with Hydrographic Survey Software HYPACK®, was used to acquire ship position and control line planning.

Side-scan sonar surveys covered a distance of 50 m on either side of the nadir for a total width of 100 m. Where there was an extensive broad reaches of shallow waters, multiple passes were completed to scan all benthic habitats between 1 and 4 meter depth. Our track line encompassed 158.3 km, with a total swath area of 12.69 km^2 (Figure 2). The breakdown for each river is summarized in Table 1.

Table 1. Area surveyed in each tributary of the Mobjack Bay within 1 and 4 m depth.

River	Area Surveyed
Severn River (with Four Points Marsh)	6.33 km^2
Ware River	2.96 km^2
North River	2.28 km^2
East River	1.12 km^2

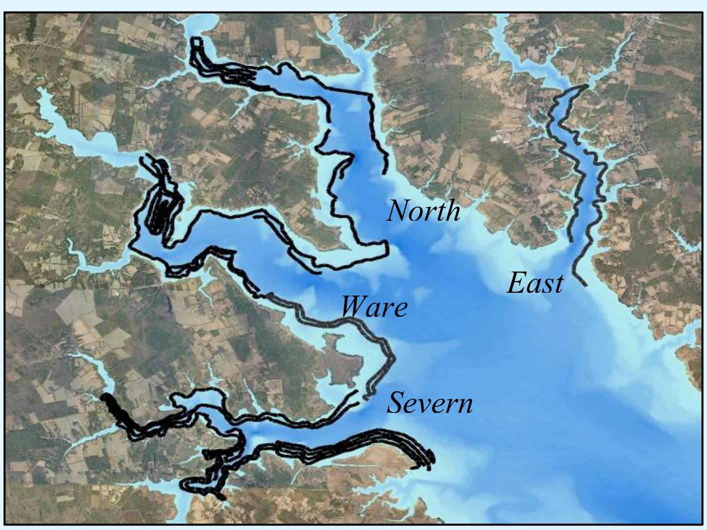


Figure 2. Acoustic survey tracklines

Acoustic Data Processing
Survey data were analyzed with *Quester Tangent* software (July-August 2007) for the entire area. The echo-sounder single beam data were processed with *QTC Impact,* and the side-scan sonar data with *QTC Sideview*. *QTC Impact* acts to read digital seabed echoes, which are processed to define boundaries of discrete acoustic classes of bottom type. Accuracy and repeatability are ensured by using only the first echo-return from the seabed. Seabed echoes are processed to present geo-referenced acoustic classes with no prior knowledge of seabed type using unsupervised classification techniques and automated 3-D clustering. *QTC Sideview* is an integrated software package that classifies sediments using the statistical properties of backscatter images. This package includes tools to perform quality assurance, analysis and classification. The processing steps included

1) **Compensation of raw images** (images of poor quality are excluded from further analyses).
2) **Generation of continuous rectangles** (129 X 17 pings) that were overlaid onto the images. Rectangle sizes were selected to achieve high resolution (~20m^2 of area/rectangle) and a manageable processing time (~4 days).
3) **Generation and clustering of image descriptions**. For each rectangle, 135 full feature vectors (image descriptors) were generated from the backscatter intensities using a suite of algorithms. During the cluster analysis, a selected range of possible acoustic signal classes (2 to 30) were run through five iterations of clustering to determine the optimum number of acoustic signal classes described in the dataset. *QTC Sideview* designates the optimum number of classes based on the lowest score (tightest clusters). Other numbers of classes with similar low scores were also considered candidates.
4) **Exporting and mapping of optimal acoustic signal classes**. For each rectangle, one acoustic class was assigned. Bottom type seabed data (XYZ file) were exported from *QTC Sideview* to GIS (e.g. ARCMAP) for spatial representation. Each rectangle was represented by an XYZ data line that was imported as points and converted into shapefiles.

Complementary acoustic datasets and associated post-processing output were used in conjunction with field observations to select five primary acoustic classes to represent benthic habitat types (Figure 3).

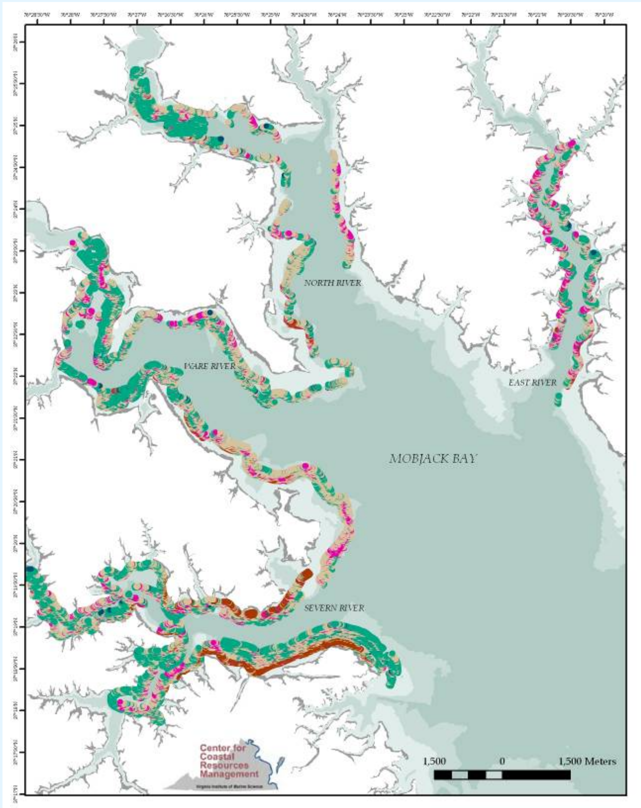


Figure 3. Benthic characterization of the Mobjack Bay based on side-scan sonar classification by *QTC Sideview*. Each color represents a unique acoustic class, which may be representative of unique surficial benthic habitat. In this image, similar colors have similar acoustic signals and thus may have similar benthic habitat characters.

GIS Processing

All data were projected and converted to the common projection (Universal Transverse Mercator (UTM) zone 18 and horizontal North American Datum 1983 (NAD83) for processing. Since each classified point in the exported *QTC Sideview* dataset represents a rectangular area, further conversion of points to polygon features was required to depict the full processed extent. The point data are used in GIS to produce thiessan polygons depicting areas of benthic habitat (5 classes) for analysis. To restrict polygons to the survey area, buffers were created around the original points and used to clip thiessan polygons. Seven meter buffers were used to closely match the estimated grid size in *QTC Sideview* (13 m x 1.5 m). Since partial grids and images near the nadir and of insufficient quality cannot be processed with the software, the classed output was less than the original surveyed area (total processed area = 3.9 km^2). The final coverage was dissolved by habitat class to create a smooth polygon surface for areal estimates of each benthic habitat class.

Bathymetric and echosounder data

Bathymetric data collected with the single beam echosounder (200 kHz) were extrapolated to create three-dimensional bathymetric models which can be overlaid with the high resolution imagery for visual interpretation of feature morphologies. The echosounder collects discrete depth points approximately 0.2 m apart depending on water depth and boat speed. To accomplish this, a Triangulated Irregular Network (TIN) was generated from bathymetric data (.XYZ) containing coordinates and depth information in ARCGIS. Elevation was displayed with a graduated color ramp and imported into ArcScene, which is a 3D visualization application that allows the overlay of many layers of GIS data in a 3D environment. To visualize the data for further interpretation with seabed classifications, side-scan sonar data are added to ArcScene and displayed in three-dimensions based on TIN heights (Figure 4).

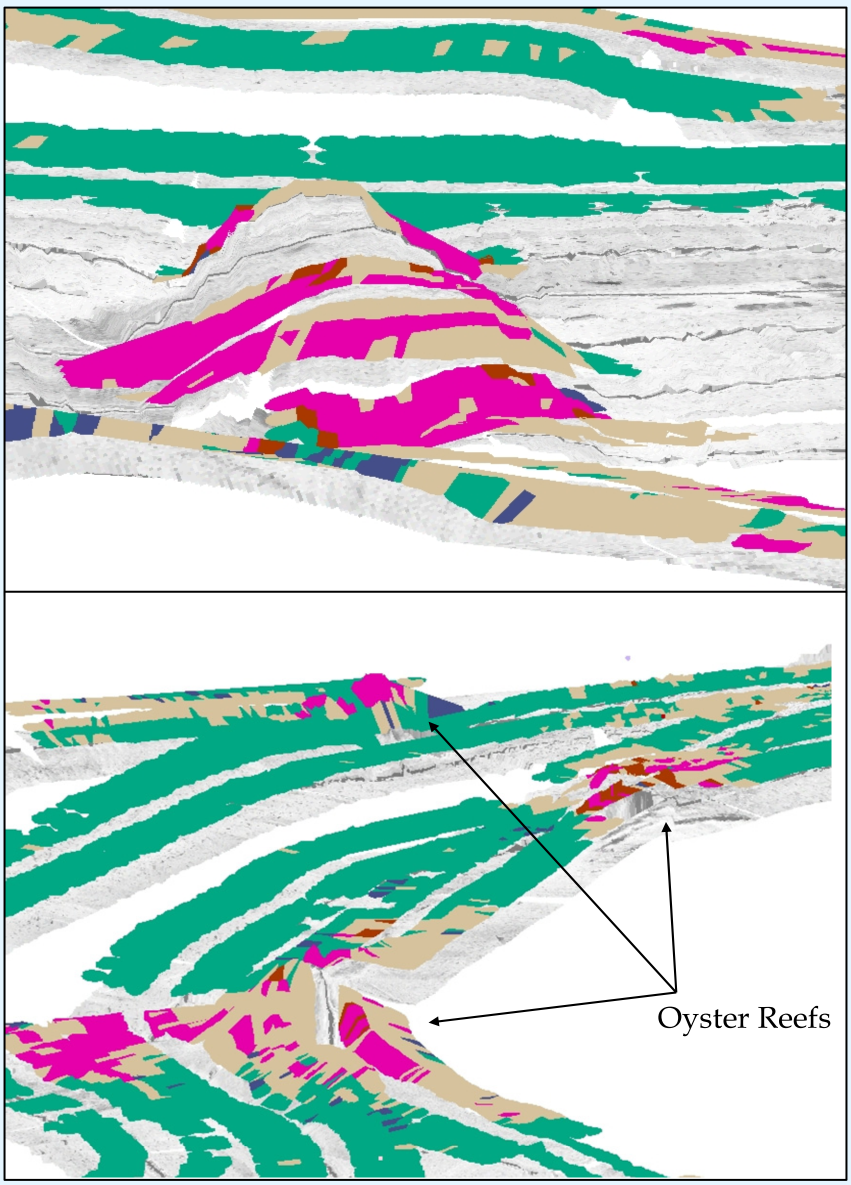


Figure 4. Three-dimensional bathymetric view of oyster reefs: a) Ware River and b) North River. Habitat classification based on side-scan acoustic imagery is overlaid on depth contours; pink coloration represents shell.

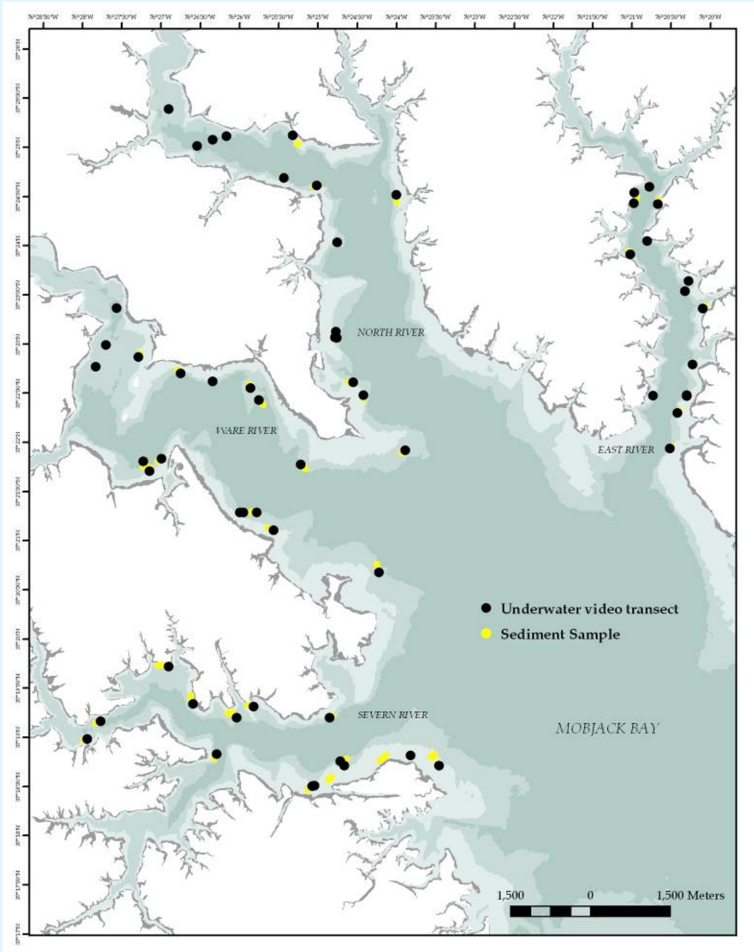


Figure 5. Underwater video and sediment sample locations for validation efforts. Video locations represent transect starting points. For each sediment probe sample, the depth of penetration was recorded and photographed for documentation. Example underwater video links are available on the dedicated website. http://ccrm.vims.edu/research/mapping_surveying/mobjack_bay/index.html

Validation of Acoustic Classification

Acoustic classes were stratified by river and three regions were randomly selected for each class in each stratum (river) for ground-truthing. Field evaluation consisted of two major elements: underwater video imagery and sediment type assessments (Figures 5 and 6). Benthic imagery was obtained with a modified benthic sled outfitted with a forward and downward-facing video camera (*Aqua-vu*), that is flown along transects at each site of a given acoustic class (Figure 3). Sediment-probes are conducted along the same transect with a handheld PVC rod with an adaptive clear piece at the end for sampling the top (~10-17 centimeters) of sediment depending on the sediment type/penetration. For each sediment probe, images are recorded of the sample (Figure 4), estimated depth of sediment layers within the probe noted, and descriptions of sediment type by percent and biogenic materials (e.g. shell, root matter) in the top and bottom layers of the sediment plug recorded independently. Information on demarcations in sediment layers is useful to relate to dual-frequency echo-sounder data which describe sediment at differing depths of penetration (i.e. 28 kHz generally penetrates deeper into the sediment than 200 kHz which describes more surficial conditions). Sites beyond the reach of the sediment probe (in excess of 3.5m), or with impenetrable conditions are assessed by physically sampling surficial sediments when necessary.

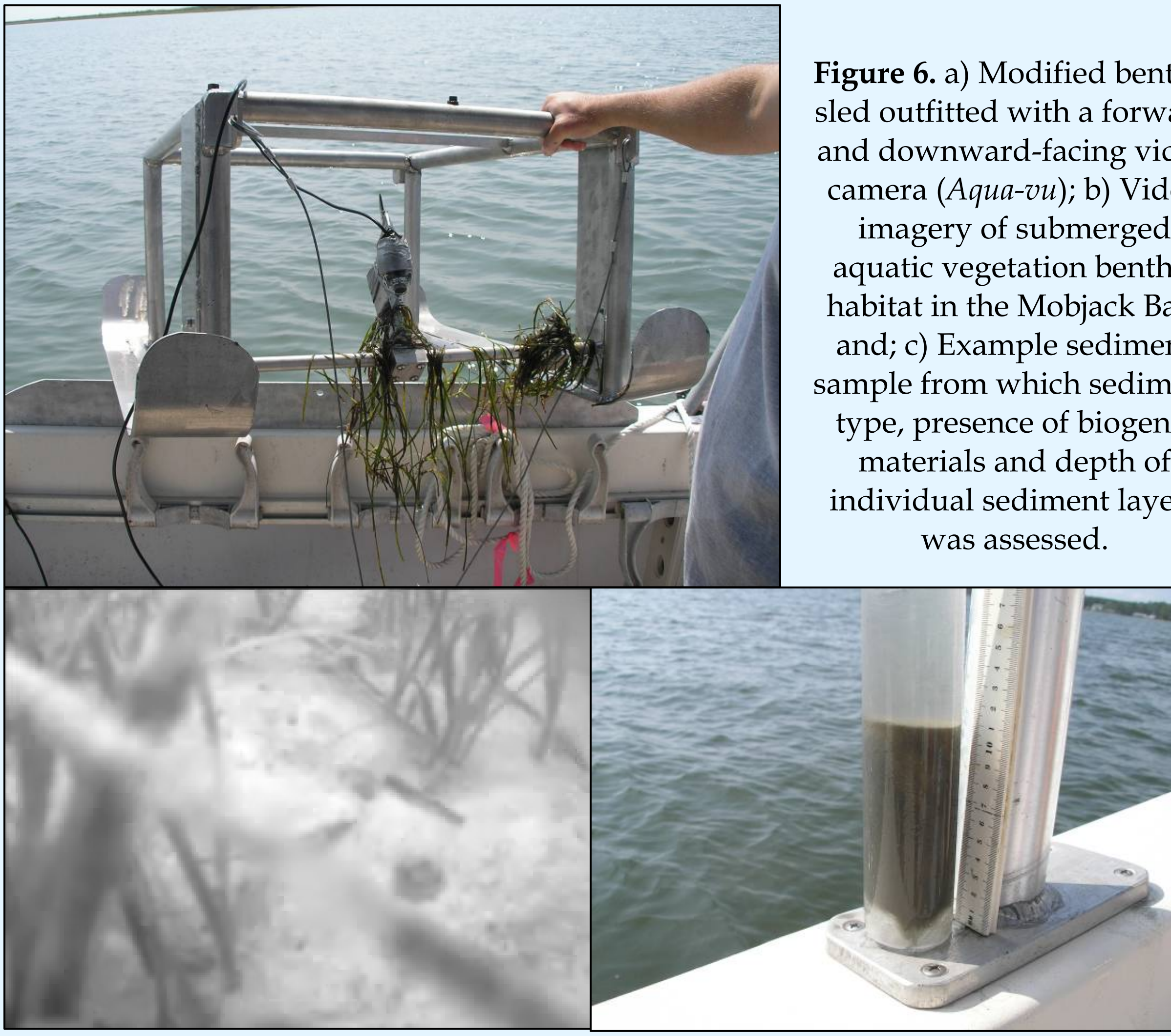


Figure 6. a) Modified benthic sled outfitted with a forward and downward-facing video camera (*Aqua-vu*); b) Video imagery of submerged aquatic vegetation benthic habitat in the Mobjack Bay, and; c) Example sediment sample from which sediment type, presence of biogenic materials and depth of individual sediment layers was assessed.

Underwater imagery was examined and summarized, ground-truth data compiled and acoustic classes associated with the appropriate benthic characterization. Single-frame underwater imagery was extracted in 10 evenly-spaced increments within the video segment. Each individual frame was assessed for amount of seabed roughness, shell, shell hash, SAV, detritus, sessile abundance, and miscellaneous features. Seabed roughness and sessile faunal abundance were independently categorized as High (> 50%), Moderate (10-50%), Low (<10%). Seabed roughness was based on surface features such as, depressions, sand ripples, worm holes or tubes or large pieces of shell. Sessile faunal abundance included organisms such as sponges, bryozoans, hydroids, coral, and barnacles. Because individually extracted frames often had lower resolution then the video, the entire video was also viewed for validation, clarification or adjustment of estimated features throughout transects, in particular for sessile faunal categorization. Additionally, geo-referenced transects were overlaid with acoustic classifications to verify that transects occurred within a contiguous area of a single class. Transects were excluded from ground-truth analysis if they 1) traversed an inseparable mix of classes, 2) were predominately located within an unclassified region, or 3) were located in an untargeted contiguous classed region. Video assessment focused on the segments that were associated with the targeted class, for example, if a targeted region was class 3 and the video traverses first into a class 1 and then into contiguous class 3 then the latter half of the video would be used for summarization Final habitat type categories were based on the average of sessile abundance and roughness with low = 1, moderate = 2 and high =3. Average values were categorized as low-moderate (1-1.49), or moderate-high (1.5-3.0). Four distinct benthic habitat types were determined based on a minimum of eight ground-truth transects per acoustic class (Table 2; Figure 7).

Table 2. Benthic habitat description by acoustic class. Counts correspond to the number of XYZ points for each class extracted from the processed seabed dataset. Area is based on the estimated size of each rectangle associated with the points. This will vary however, and therefore is not exact. The approximate area processed was 3.9 km^2. FS-S represents fine sand and silt sediment type. The small and sporadic number of blue points resulted in an undetermined habitat type, most likely this class is associated with a relative deepening of water.

Class	Counts	Area (km^2)	%	Habitat Type
Red	15832	0.31	8	Submerged Aquatic Vegetation
Pink	19097	0.37	9.5	Shell
Green	76707	1.5	38.5	Fine sand & silt (FS-S) with moderate-high roughness & sessile abundance
Tan	79687	1.6	41	Fine sand & silt (FS-S) with low-moderate roughness & sessile abundance
Blue	6212	0.12	3	Relatively deep, undetermined

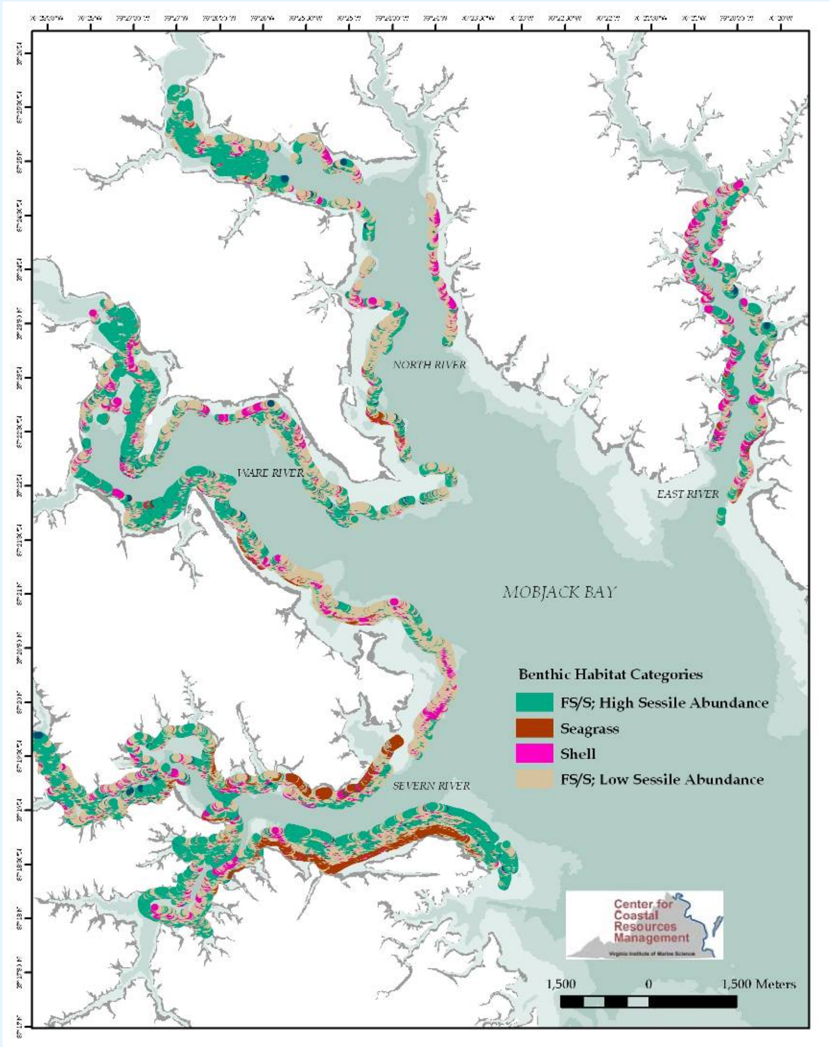


Figure 7. Spatial distribution of nearshore subtidal benthic habitat in the Mobjack Bay including seagrasses and oyster shell.

Habitat Validation – Auxiliary data

Auxiliary datasets, such as VIMS aerial submerged aquatic vegetation monitoring surveys, were overlaid with benthic characterization for validation from a secondary source in overlapping areas. Preliminary aerial survey data from 2007, spatially displayed with our acoustic surveys, indicated a consistent overlap in regions with identified SAV. The SAV aerial survey can delineate SAV within the shallows (<1 m depth) which the side-scan sonar survey could not cover effectively due to harsh backscatter overwhelming imagery. In reaches where SAV was present in deeper waters (> 1m) and often non- identifiable in aerial survey images, SAV was accurately delineated with acoustic imaging at small spatial resolutions (~20m^2). Aerial survey estimates in concert with ground-truth information validated the benthic categorization output. Likewise, known oyster reef locations were accurately categorized with the side-scan sonar imagery. Additional oyster shell habitat located by benthic mapping may be useful for targeting of future restoration efforts (Figures 8 and 9).

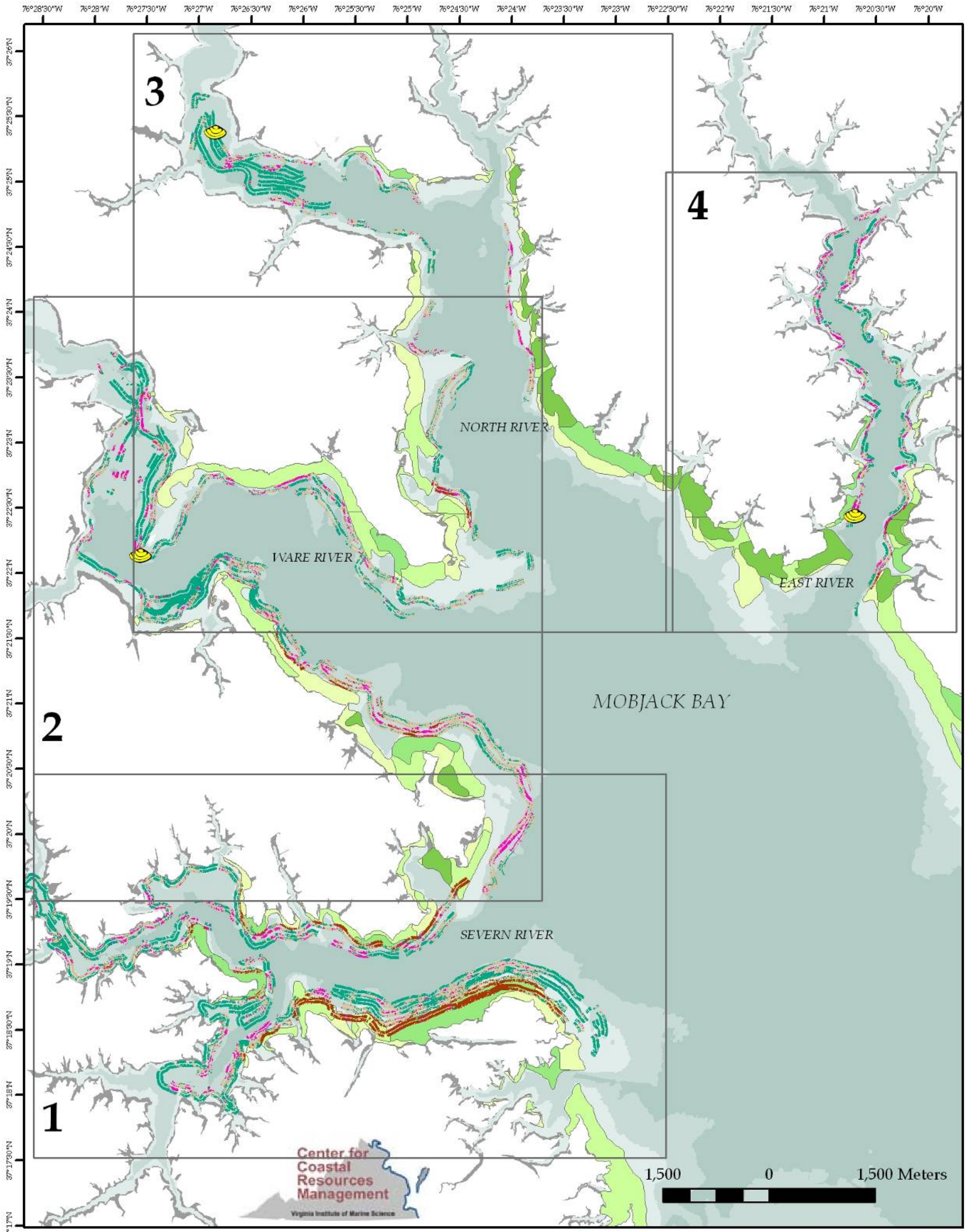


Figure 8. Index map of river segments within the Mobjack Bay: 1) Severn, 2) Ware, 3) North and 4) East Rivers.

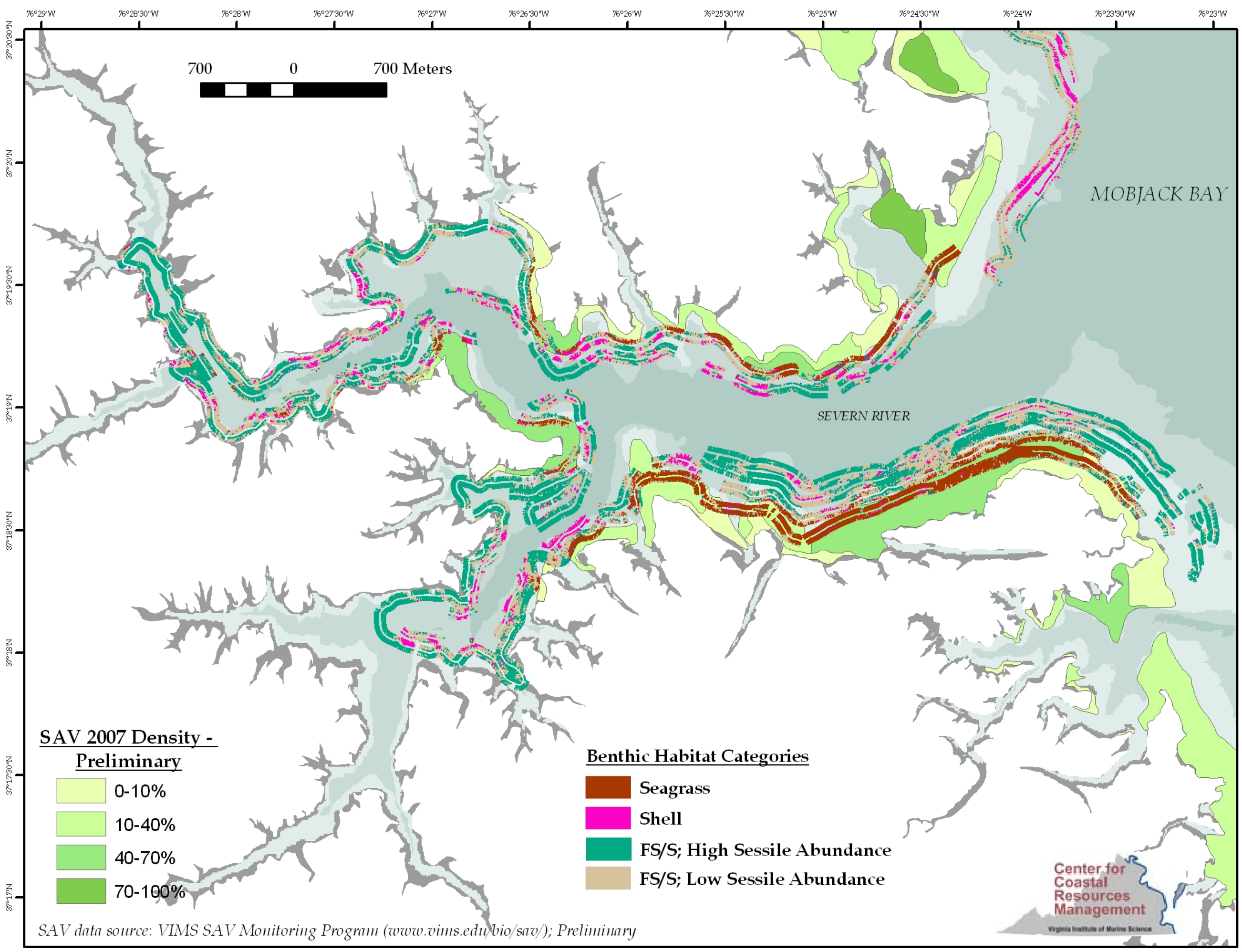
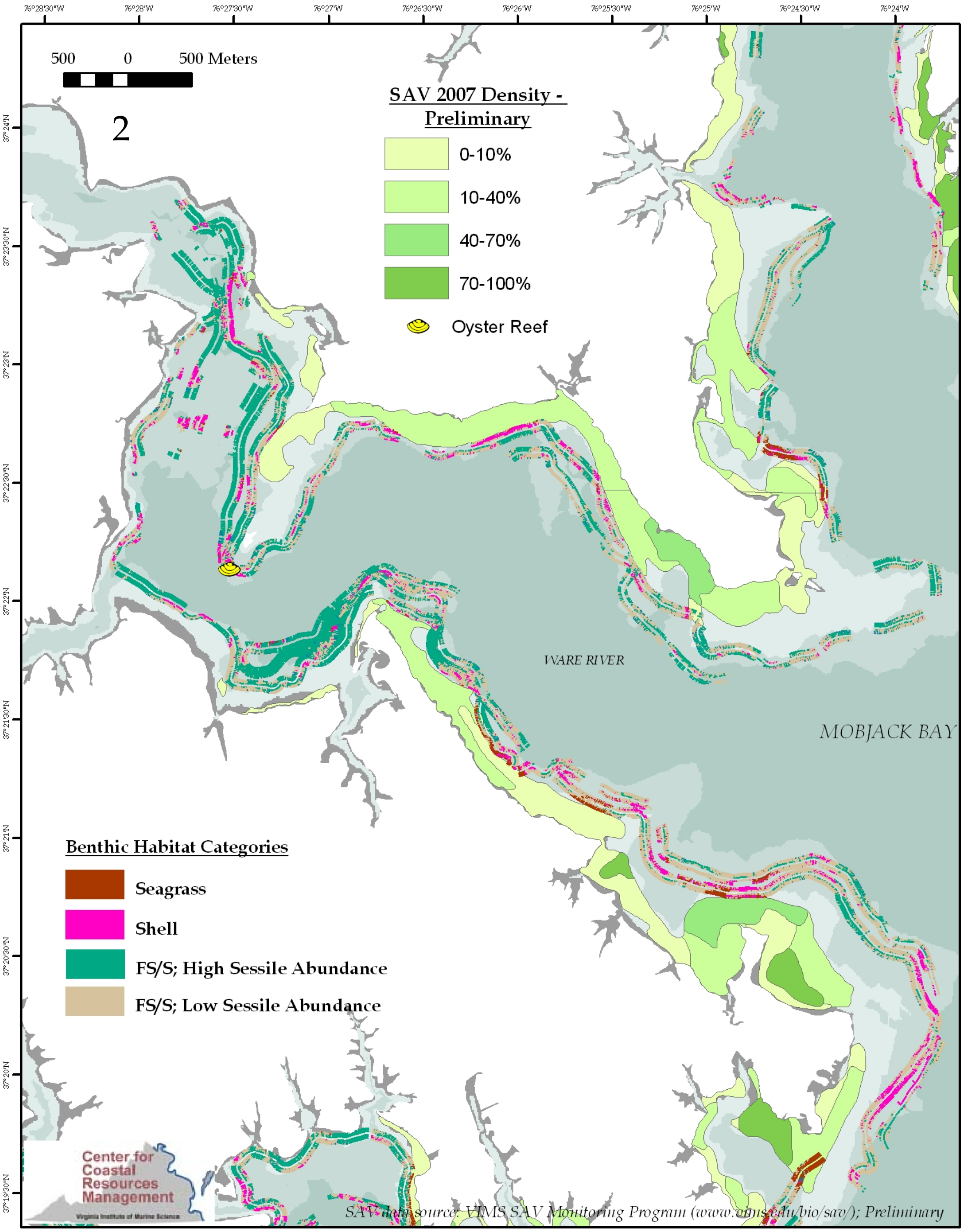


Figure 9. Benthic habitat characterization from acoustic survey with secondary data overlaid: SAV aerial estimates from the SAV mapping program and restoration oyster reef locations for Severn River (Segment 1), Ware River (Segment 2), North River (Segment 3), and East River (Segment 4). FS/S represents fine sand & silt sediment. Map segments 2-4 on subsequent pages.


500 0 500 Meters
2
SAV 2007 Density - Preliminary
0-10%
10-40%
40-70%
70-100%
Oyster Reef
WARE RIVER
MOBJACK BAY
Benthic Habitat Categories
Seagrass
Shell
FS/S; High Sessile Abundance
FS/S; Low Sessile Abundance
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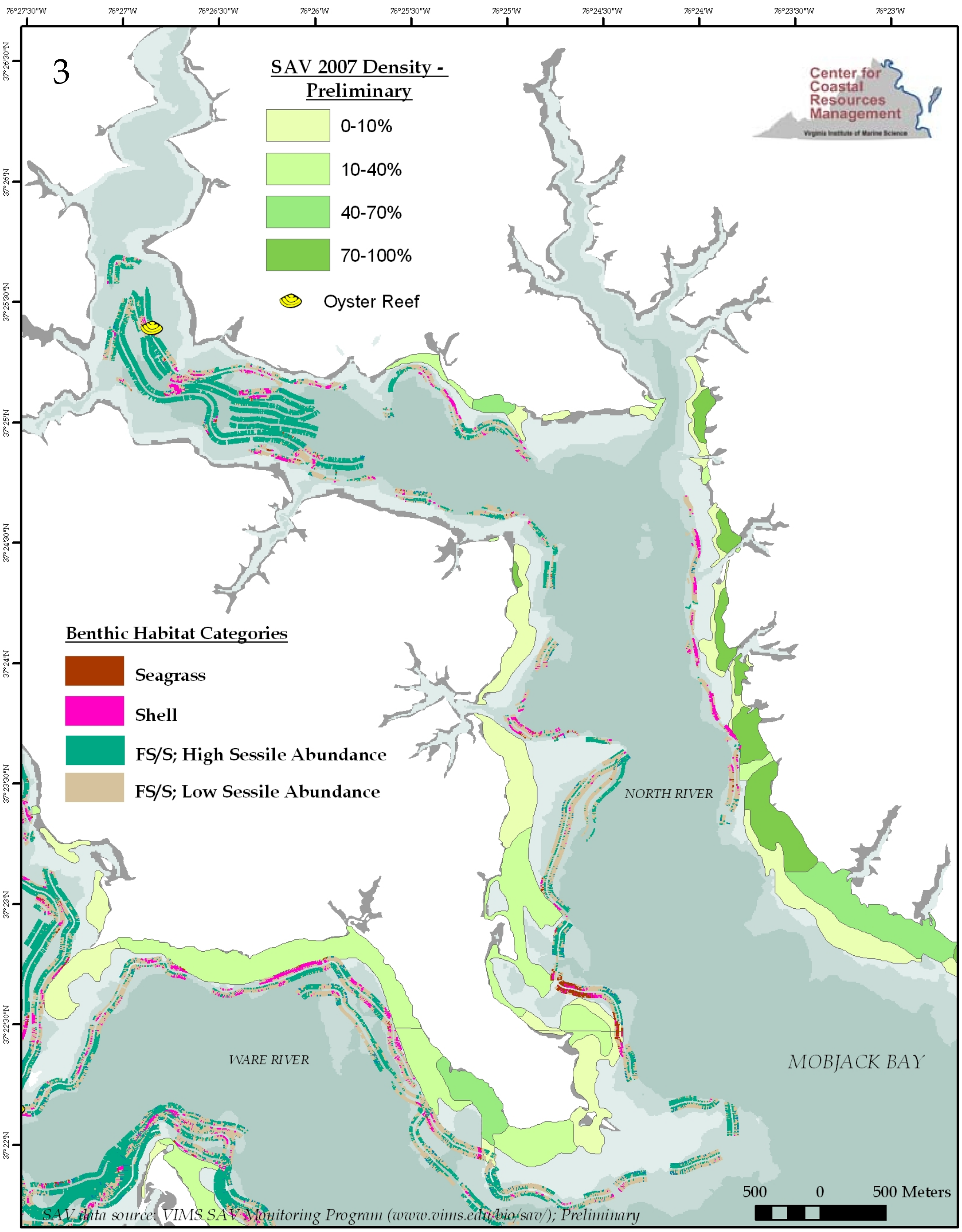
Virginia Institute of Marine Science
SAV data source: VIMS SAV Monitoring Program (www.vims.edu/bio/sav/); Preliminary


76°27'30"W
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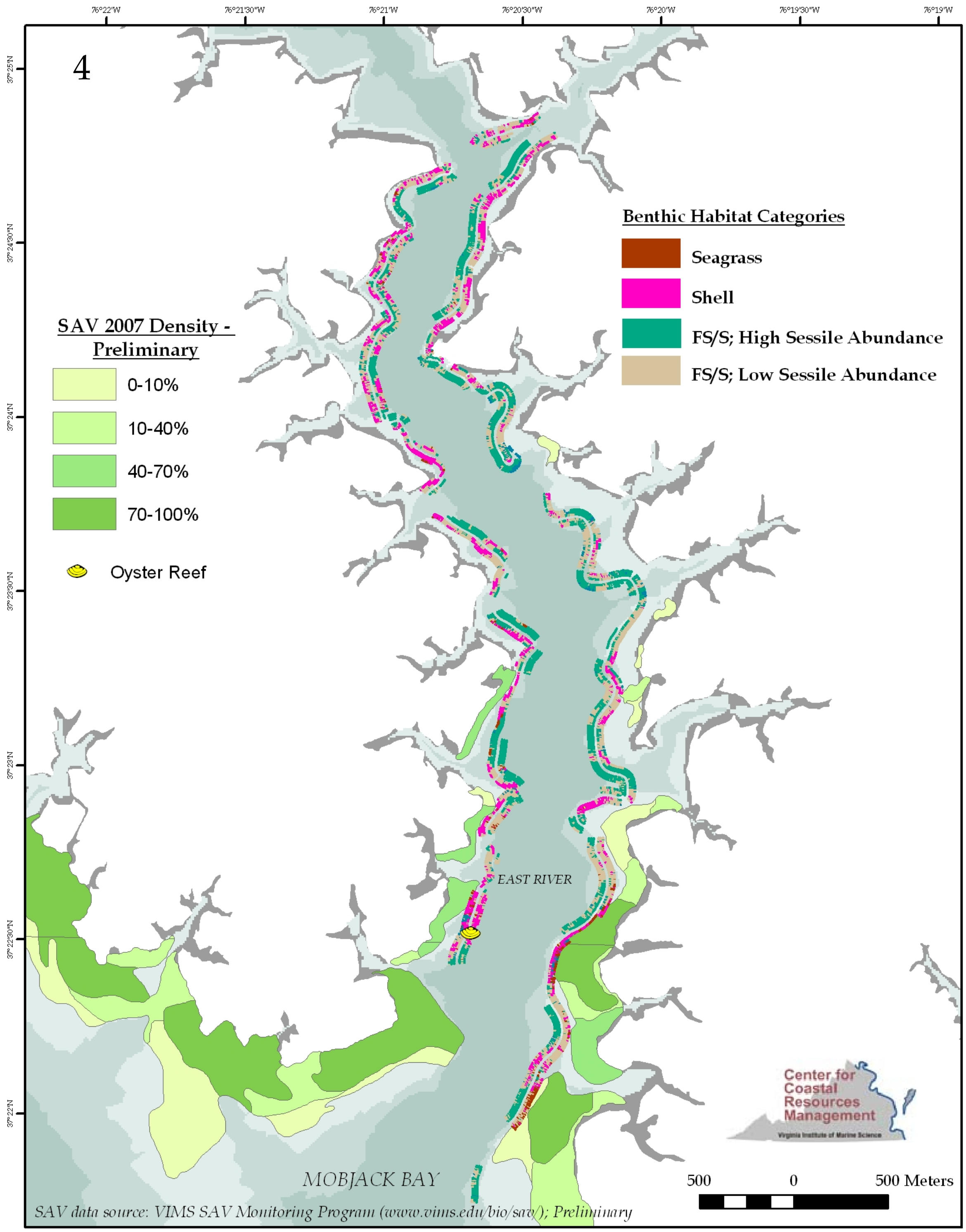
37°25'N
37°24'30"N
37°24'N
37°23'30"N
37°23'N
37°22'30"N
37°22'N
3
SAV 2007 Density - Preliminary
0-10%
10-40%
40-70%
70-100%
Oyster Reef
Center for Coastal Resources Management
Virginia Institute of Marine Science
Benthic Habitat Categories
Seagrass
Shell
FS/S; High Sessile Abundance
FS/S; Low Sessile Abundance
NORTH RIVER
WARE RIVER
MOBJACK BAY
500 0 500 Meters
SAV data source: VIMS SAV Monitoring Program (www.vims.edu/bio/sav/); Preliminary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76°21'30"W
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37°25'N
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37°24'N
37°23'30"N
37°23'N
37°22'30"N
37°22'N
4
Benthic Habitat Categories
Seagrass
Shell
FS/S; High Sessile Abundance
FS/S; Low Sessile Abundance
SAV 2007 Density - Preliminary
0-10%
10-40%
40-70%
70-100%
Oyster Reef
EAST RIVER
MOBJACK BAY
SAV data source: VIMS SAV Monitoring Program (www.vims.edu/bio/sav/); Preliminary
500
0
500 Meters
Center for Coastal Resources Management

Digital products (on CD and internet)

Benthic Habitat_MobjackBay (ArcMap Project)

1) **BenthicHabitat** - geo-referenced depictions of aquatic habitat distributions for the nearshore of Mobjack Bay (coverage - polygon)
2) **BenthicHabitat_Pt –** extracted point coverage representing classified areas of benthic habitat with tabular positional information (coverage - point)
3) **Sediment Samples** – location of ground-truth sites where sediment probes were conducted (shapefile – point)
4) **Underwater Video Transects** - location of ground-truth sites with benthic video imagery (shapefile – point)

Bathymetry_Mobjack (ArcScene Project)

1) **Seabed Imagery –** Individual geo-tiff files for each river system of nearshore seabed imagery from side-scan sonar surveys.
2) **Bathymetry -** three-dimensional bathymetric models based on single-beam depth data which can be overlaid with the high resolution imagery for visual interpretation of feature morphologies

Internet Files

1) **Video –**video imagery files (.wmx) of ground-truth locations linked on website
3) **Website –** http://ccrm.vims.edu/research/mapping_surveying/mobjack_bay/index.html

Summary

Acoustic benthic habitat characterization is a valuable tool in dynamic estuary systems in which low water column visibility is common and visual survey methodology impractical. Reaches of subtidal habitat insufficiently defined in aerial imagery were successfully identified with acoustic systems. We were able to survey, map and quantify benthic habitat within the nearshore of Mobjack Bay using remote-sensing technologies and classification software. These technologies are especially useful to produce digital geospatial characterization of the extent and distribution of prevalent nearshore habitats, including submerged aquatic vegetation and oyster shell habitat. Benthic habitat data have numerous applications in management and research, for example, 1) assessments of biotic interrelationships among habitats, 2) evaluations of specific spatial arrangements of habitat for ecological significance, and 3) targeting of restoration or conservation sites. A current data need is information on the distribution of nearshore habitats, which are most susceptible to sea level rise and climate change stressors, to inform climate change models striving to predict shifts in ecosystem function under varying future scenarios.

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