Atlantic Sturgeon Spawning Habitat on the James River, Virginia

Final Report to NOAA/ NOAA Chesapeake Bay Office

D. M. Bilkovic, K. Angstadt, and D. Stanhope

Virginia Institute of Marine Science

Center for Coastal Resources Management

Gloucester Point, Virginia

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FINAL REPORT

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Prepared By
Center for Coastal Resources Management
Virginia Institute of Marine Science, College of William and Mary
Gloucester Point, Virginia 23062

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Introduction
The Atlantic sturgeon is an anadromous species that migrates from the ocean into coastal estuaries and rivers to spawn. In the Chesapeake Bay, Atlantic sturgeon historically spawned in all the major tributaries of the Bay. Presently, spawning populations have been drastically reduced due to overfishing, pollution, dam construction and habitat degradation. Low sturgeon population levels have hindered the location of viable spawning reaches through direct observation of habitat use within Virginia’s major tributaries, James, York, and Rappahannock. However, anecdotal evidence and the capture of early juveniles indicate the possibility of successful spawning occurring in the James and York Rivers. Vital to the restoration of Atlantic sturgeon populations in Virginia, is an understanding of the quantity and quality of available suitable spawning and nursery habitat.

Several habitat parameters are hypothesized to be essential for viable spawning, including salinity (salt front to the fall line), hydrodynamic complexity (e.g. eddies with fast moving flowing reaches), high dissolved oxygen (>4mg/L), and proper spawning substrate to facilitate adhesion of eggs. The location of reaches of hard bottom benthic habitat which is a probable limiting factor for successful spawning (Bushnoe et al. 2005) will enhance Atlantic sturgeon restoration efforts. Using acoustic surveys and specialized post-processing techniques (side-scan sonar, classification software and underwater videography), we identified suitable spawning substrate (rock, gravel, cobble) within the known range of historic spawning in the James River, Virginia. Results are geo-referenced within Geographic Information Systems (GIS) allowing for the incorporation of additional habitat quality information to develop spatially-explicit habitat suitability models.

Objectives
- Assess the availability of suitable spawning habitat in the James River for Atlantic Sturgeon by characterizing benthic habitat with acoustic surveys within the known range of historic spawning.
- Delineate and geo-reference the location of viable hard bottom spawning habitats for future evaluation with additional habitat quality information.
Methods

Acoustic Data Processing
To characterize surficial benthic habitat, riverbed imagery within the tidal freshwater reaches of the James River (Turkey Island Cutoff to immediately downriver of Richmond) and the Appomattox River was obtained with a high-resolution remote sensing system (Marine Sonics 600 KHz side-scan transducer; imagery acquisition funded by USFWS in 2005-2006) and classified into similar acoustic signal categories (Figure 1). Side-scan sonar has the ability to map swath transects (in this case 50m swaths) of benthic habitat, and was towed to collect real-time, geo-referenced, riverbed mosaic data with overlapping edges matched to form a continuous profile of the bottom. This equipment provided high-resolution digital images of the surface structure of the benthic environment. During scanning, annotations of prominent features were geo-referenced on images (e.g. rock, woody debris). The acoustic signal of bottom was categorized with classification software *QTC SIDEVIEW* developed by Quester Tangent, and geo-referenced profiles were converted to GIS coverages that depict areas of classified habitats.

*QTC SIDEVIEW* is an integrated software package that classifies sediments using the statistical properties of backscatter images, and includes tools to perform quality assurance, analysis and classification. An inherent limitation of the software is that partial grids (overlaid prior to classification) and images near the nadir or of poor quality cannot be processed; therefore, classed output will cover a subset of the original surveyed area. The processing steps include...

Figure 1. Location of benthic habitat survey on the James & Appomattox rivers, Virginia
1) **Compensation of raw images** (images of poor quality are excluded from further analyses).

2) **Generation of continuous rectangles** (65 X 17 pings) that were overlaid onto the images. Rectangle sizes were selected to achieve high resolution (~10m² of area/rectangle) and a manageable processing time (~4 days) (example grid, Figure 2).

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. Each acoustic class is assigned a color by the software and classes with similar colors have similar acoustic signatures (bottom types).

Complementary acoustic datasets and associated post-processing output were used in conjunction with field observations to select four primary acoustic classes to represent benthic habitat types in the James and Appomattox tidal freshwater systems.

**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 allows for the depiction of the full processed extent. The point data are used in GIS to produce thieessen polygons depicting areas of benthic habitat (4 classes) for analysis. To restrict polygons to the survey area, buffers were created around the original points and used to clip thieessen polygons. Five meter buffers were used to closely match the estimated grid size in *QTC SIDEVIEW* (6.5 x 1.5 m). Since partial grids and images near the nadir and of poor quality cannot be processed with the software, the classed output was less than the original surveyed area (surveyed area ~ 8.5 km²; total processed area ~ 5.8 km² (69% of survey processed)). The final coverage was dissolved by habitat class to create a smooth polygon surface for areal estimates of each benthic habitat class (Figure 3).
Figure 2. High resolution image classification of Turkey Island Cutoff, James River with acoustic classes overlaid as points. Each point represents the centroid location of a rectangular grid (example grid displayed in inset) for which benthic data has been integrated. The dark line is the nadir (boat track). Red and pink classes (top) represent hard substrate, for example, gravel, cobble and rock; blue and green classes are soft sediment signatures with varying benthic complexity.
Validation of Acoustic Classification

A minimum of six regions for each of the four classified habitat types were selected for ground-truthing in March-April 2008 (Figure 4). Field evaluation consisted of two major elements: underwater video imagery and fine resolution sonar scans (20 m swaths) and echosounder (Knudsen 320 BP; Kel 28/200 kHz dual-frequency transducer) technology. Sonar scans covered short riverbed reaches, typically less than 500m, of contiguous benthic habitat for validation of classifications. Benthic imagery was obtained along transects at each site of a given acoustic class with a modified benthic sled outfitted with forward and downward-facing video cameras (Aqua-vu) or with a lowered line with camera attached (Figure 5). Underwater imagery was examined and summarized, ground-truth data compiled and acoustic classes associated with the appropriate benthic characterization.
Figure 4. Ground-truth survey locations by acoustic class conducted in Mar-Apr 2008
Results

Four distinct classes were defined by post-processing acoustic imagery with QTC SIDEVIEW and ground-truth surveys: i) sand/silt, ii) sand with bottom complexity (e.g. shell, benthic growth), iii) rock/bedrock, and iv) gravel/cobble/pebble (Table 1). Primary habitats of interest, defined here as acoustic signature classes red and pink (rock and gravel/cobble), were observed in varying amounts throughout the entire surveyed area. Maps appended display benthic information for the entire river as well as for 6 detailed segments of the James River in two formats (all benthic classes and only hard benthic substrate habitat) (Figures 6-19). Overall, approximately 20% (1.2km²) of the processed James riverbed was associated with hard substrate classifications. While the ground-truth activities supported the designated categorization, it is possible that similar acoustic signatures may represent other hard substrate or sudden shifts in depth, for instance woody debris, artificial hard structures (derelict pilings, shoreline
features), or an abrupt sand bar. Although the Appomattox River survey was processed for benthic characterization, poor imagery due to channel morphology and technological limitations (e.g., extreme depth variation or abrupt drop-offs to channel) in some reaches reduced our confidence in the classification output. Hard acoustic signatures may not be reflecting true benthic features, but artificial signals due to depth variation and shoreline returns. Data are summarized (Table 1) and maps of benthic habitat included (Figures 20-21), but further ground-truth validation is required in this system.

During ground-truth activities in 25-27 March 2008, large fish (> 0.5m) were observed and annotated on high-resolution scans. While definitive fish identification cannot be assigned, fish in excess of 1-m present in the upper tidal James during this time period have a high probability of being Atlantic sturgeon. Fish were observed in the vicinity of Turkey Island and Jones Neck oxbows and at Lower Rocketts downriver of Richmond (Figure 22).

Table 1. Point counts and associated area estimates for each benthic habitat type (a) James River, (b) Appomattox River. Similar colors pink and red are associated with hard substrate. Blue is associated with sand/silt and Green, which was the most common bottom type, is predominantly sand with complex bottom, such as shell, sessile abundance/bottom growth. Black was an inconsistent sediment type that was unverifiable due to its patchy nature and association with deep channels, and may be related to abrupt shifts in depth or general technological errors. Extrapolation of point information to a given area (thiessen polygon analysis) was constrained by the size of the original grid (6.5 x 1.5 m) overlaid on images for conservative habitat estimation.

<table>
<thead>
<tr>
<th>Class</th>
<th>Initial Counts</th>
<th>Polygon Area (m²)</th>
<th>Area (km²)</th>
<th>Percent of processed area</th>
<th>Habitat Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink</td>
<td>7,098</td>
<td>180,914</td>
<td>0.2</td>
<td>3.1</td>
<td>Gravel/Cobble</td>
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<tr>
<td>Red</td>
<td>37,607</td>
<td>951,780</td>
<td>1.0</td>
<td>16.4</td>
<td>Rock</td>
</tr>
<tr>
<td>Blue</td>
<td>32,006</td>
<td>790,113</td>
<td>0.8</td>
<td>13.6</td>
<td>Sand/Silt</td>
</tr>
<tr>
<td>Green</td>
<td>151,121</td>
<td>3,760,918</td>
<td>3.8</td>
<td>64.7</td>
<td>Sand with complex bottom</td>
</tr>
<tr>
<td>Black</td>
<td>4,813</td>
<td>126,765</td>
<td>0.1</td>
<td>2.2</td>
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<tr>
<td>Total</td>
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<td>5,810,490</td>
<td>5.8</td>
<td>100</td>
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<table>
<thead>
<tr>
<th>Class</th>
<th>Initial Counts</th>
<th>Polygon Area (m²)</th>
<th>Area (km²)</th>
<th>Percent of processed area</th>
<th>Habitat Type</th>
</tr>
</thead>
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<td>45,068</td>
<td>0.05</td>
<td>3.3</td>
<td>Gravel/Cobble</td>
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<tr>
<td>Red</td>
<td>10,599</td>
<td>256,310</td>
<td>0.26</td>
<td>18.5</td>
<td>Rock</td>
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<tr>
<td>Blue</td>
<td>5,049</td>
<td>132,267</td>
<td>0.13</td>
<td>9.6</td>
<td>Sand/Silt</td>
</tr>
<tr>
<td>Green</td>
<td>34,960</td>
<td>856,264</td>
<td>0.86</td>
<td>61.9</td>
<td>Sand with complex bottom</td>
</tr>
<tr>
<td>Black</td>
<td>3,714</td>
<td>93,692</td>
<td>0.09</td>
<td>6.8</td>
<td>Unknown</td>
</tr>
<tr>
<td>Total</td>
<td>56,096</td>
<td>1,383,601</td>
<td>1.4</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

When considering restoration/conservation activities, these data may be used to locate suitable hard bottom substrate for Atlantic sturgeon spawning. In combination, the hard signature classes represent hard structures or substrate currently in the upper tidal freshwater James, which are preferred spawning habitats. Over the processed area of the James River (5.8 km²), approximately 20% (1.2 km²) of the riverbed was associated with hard substrate classifications. However, some designated reaches may not have viable spawning conditions; therefore, site-specific activities, such as spawning habitat enhancements, require further verification of habitat viability during the targeting process. For example, absent from the characterization is a complete quantification of surface silt-layer that may reduce the quality of spawning habitat substrate. Underwater video at select river areas can be used to qualitatively assess siltation problems on a limited temporal scale. Prior to any restoration activities designed to augment spawning substrate, longer term intensive evaluations of siltation patterns on site are necessary. The benthic characterization does provide valuable spatially-explicit information on available spawning habitats in the James River, and can be used as a tool for targeting potential restoration/conservation reaches as well as habitat suitability modeling.

The ability to quantify available suitable spawning habitat for depressed Atlantic sturgeon populations is critical to resource managers looking for site-specific guidance for impact assessments. Spawning/nursery habitat may be affected by a myriad of managed activities including i) dredging (disruption/destruction of spawning habitat/feeding areas); ii) outfalls (extreme temperature changes leading to mortality or reduced growth); iii) water withdrawals (impingement or entrainment mortalities/injuries, flow alterations shifting essential habitat); and iv) boat traffic-commercial/recreational (fish strikes, migration interruptions). The development of an adaptive comprehensive management and planning tool which incorporates 1) habitat requirements for Atlantic sturgeon and other target groups, 2) present habitat conditions, and 3) current and future predicted use-conflict in key habitats is needed to support management decisions. Ideally, this planning tool would model alterations to habitat as management actions are considered, and climate changes occur or are predicted. Further applications would be to target restoration or conservation areas of essential habitat.

Literature Cited

Figure 6. Benthic habitat based on acoustic signature classification from QTC SIDEVIEW. Individual Plates I-VI provide more detail below.
Figure 7. Hard substrate locations based on acoustic signature classification with QTC SIDEVIEW. Individual Plates I-VI provide more detail below.
Figure 8. Plate I – Turkey Island Oxbow. Benthic habitat characterization.
Figure 9. Plate I – Turkey Island Oxbow. Hard substrate benthic habitat.
**Benthic Habitat**

**James River - Jones Neck - Plate II**

Figure 10. Plate II – Jones Neck Oxbow. Benthic habitat characterization.
Figure 11. Plate II – Jones Neck Oxbow. Hard substrate benthic habitat
Figure 12. Plate III – Dutch Gap. Benthic habitat characterization
Figure 13. Plate III - Dutch Gap. Hard substrate benthic habitat.
Figure 14. Plate IV – Chaffin Bluff. Benthic habitat characterization.
Figure 15. Plate IV – Chaffin Bluff. Hard substrate benthic habitat.
Figure 16. Plate V – Deepwater Terminal. Benthic habitat characterization
Figure 17. Plate V – Deepwater Terminal. Hard substrate benthic habitat
Figure 18. Plate VI – Rocketts near Richmond. Benthic habitat characterization
Figure 19. Plate VI – Rocketts near Richmond. Hard substrate benthic habitat
Figure 20. Appomattox River. Benthic habitat characterization
Figure 21. Appomattox River. Hard substrate benthic habitat
Figure 22. Large fish (0.5-1.5m) observations during ground-truth activities (side-scan sonar high resolution scans of select ground-truth reaches) in March 25-27, 2008.