Landscape Level In-Stream Habitat Mapping Using Side Scan Sonar

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The research and management of stream fish habitat at the landscape level poses a number of challenges.

Characterization of in-stream habitat at the landscape scale is notably difficult and costly, especially in non-wadeable, turbid systems.

Our understanding of river processes is largely based on locally intensive mapping of stream reaches, or on spatially extensive but low density data scattered throughout a watershed.
Challenges

• Traditional approaches (i.e., field sampling)
  – Labor intensive
  – Wadeable, non-turbid streams
  – Small scale (spot or transect-based sampling)
  – Interpolated to provide continuous coverage

• Hi-Tech approaches (LiDAR, RADAR, Thermal mapping)
  – Costly
  – Physical limitations – depth, turbidity, canopy cover
  – Technical expertise
  – Specialized software
Why Side Scan Sonar?

- Side scan sonar for benthic mapping
  - Efficient
  - Low-cost

- Mapping habitat features
  - High resolution
  - Spatially detailed
  - Continuous, in-stream habitat
  - Across broad aquatic landscapes
    - Navigable rivers and streams
  - Identify substrate, large woody debris, depth
What is Side Scan Sonar?

• **Acoustic Pulses**
  – Travel through the water column
  – Strike objects or bottom
  – Reflected back to transducer

• **Return pulses**
  – Travel time
  – Amplitude (strength)

Amplitude is affected by:

- Density of object or surface
  - Dense, hard objects (boulders, bridge abutments), reflect more energy (darker tone)
  - Soft surfaces (mud) reflect less energy (lighter tone)
- Water density (plumes of water of different temperatures)
- Suspended particulates
- Turbulence
Sonar systems first developed in the early 1900s.

In 2005 the Humminbird® Company introduced the first recreational grade side scan sonar system.
  - The Humminbird® Side Imaging (HSI) system
    - High quality imagery at a very low price
    - Small adjustable transducer that can be deployed on a small watercraft.

Humminbird® primarily markets the system to professional and serious amateur fishermen, although several other user groups, like divers, have also embraced the product.
Background - Methodology

• Adam Kaeser began using Sonar in 2006
  • Georgia Dept. of Natural Resources
  • Surveying for sunken pre-cut logs (deadhead logs)
Background - Methodology

- Adam Kaeser and Thomas Litts (GIS)
  - Pioneered a method for using sonar for large-scale underwater habitat

Chipola River – Shoal Bass Project

- FWC - 2010
  - Training session - Kaeser and Litts
  - Data collection - FWRI\FFR
  - Data analyses - FWRI\IS&M\CSA

- Two phases
  - Upper Chipola – 45 km
  - Lower Chipola – 23 km
Process Steps

• Data collection – field sonar surveys

• Georeferencing and transformation

• Mapping of in-stream habitat features – image interpretation and manual digitization
  • Banks
  • Substrates
  • Depth
  • LWD (large woody debris)

• Accuracy assessment

• *Following methodology developed by Kaeser and Litts
Data Collection - Equipment

• Control head
  – Humminbird 900 or 1100 series (1197c)
  – SD Card for data storage

• Transducer/Transmitter
  – 1100 Series
  – Front mount recommended – Prop-wash

• Global Positioning System (GPS)
  – Garmin GPSmap 76, 76C, 76CSx
  – WAAS enabled (3-5m accuracy)

• Interval Timer (stopwatch)
Data Collection

- During high water – streams at “bankfull level”
- Screen snapshot approach
  - Capture of digital image (PNG) (SD Card) and waypoint (control head) simultaneously
  - Discrete point in time
  - Dictated by the operator
    - Approx. every 6 seconds
  - Coordinates for survey track (Trackpoints)
  - Side beam (width of capture), 90’ per side

- Boat operation
  - Maintain mid-channel position
  - Speed at approximately 3.5 to 6 mph
  - Downstream
Transfer images
Water Column – No missing data

Objects directly beneath the transducer appear as mirror images on either side

Software Requirements

• ArcGIS 9.2 (or greater)
• ET Geowizards
• Irfanview

• Sonar Tools*

* Kaeser and Litts
Inspecting and Cleaning the Data
- Waypoints checked for correct positioning and divided into segments (21 processing segments)
- Segment of 50 or fewer waypoints were preferable

Track Line Processing
- Converted points into a line
  - Point to Polyline function (ET Geowizard extension for ArcGIS 9.2)
- Smoothed the line
  - Bezier curve method in the Smooth function (ET Geowizard extension for ArcGIS 9.2)
  - Smoothness set to 5
  - Tolerance of 2 meters
- Checked the waypoint file for proper sequencing of points in the attribute table
- Split the smoothed line at the waypoints – Split Polyline with Layer function (ET Geowizard extension for ArcGIS 9.2)
Result: Series of line segments representing the distance between waypoints and the non-overlapping portion of the sonar imagery.
Image Processing

- Remove collar information
- Clipped the overlapping portion of the images
  - Irfanview software
  - Image matching Tool – Kaeser and Litts processing toolbox
- Manually selected a match point when no overlap was identified by the image matching algorithm
  - Point Selector tool – Kaeser and Litts processing toolbox
- Transformed each clipped sonar image into a geo-referenced raster
  - Batch Rectify Tool - Kaeser and Litts processing toolbox
Warped images

- Tight bends in the river
- Anomolies in the trackline

- Convert the text file (created during the control point generation) to a format that can be viewed in ArcGIS
- Identify and delete the incorrect control points
- Re-run the rectification step
- Repeat until the image is satisfactory
Mosaic rectified sonar images into one large image
- Batch Mosaic Generation Tool – Kaeser and Litts processing toolbox
- Generates a .txt file that is run in the command line

Repeat all steps for each of the processing segments

Add all final mosaics to an ArcGIS map and overlay on a DEM to check for locational accuracy
Polygon Creation

• Create shapefile representing the stream banks
  – Digitize the outline of the mosaicked sonar images
Polygon Creation

- Digitize substrate polygons
  - Visual interpretation
  - Texture and tone

Identifying Substrate Types
**Substrate Types**

Table 1: Classification scheme developed by FWRI biologist to identify substrate types from side-scan sonar data.

<table>
<thead>
<tr>
<th>Substrate type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/ Pea gravel</td>
<td>S</td>
<td>An area predominately (&gt;75%) composed of particles &lt; 5 cm</td>
</tr>
<tr>
<td>Rocky fine</td>
<td>RF</td>
<td>An area predominately composed of rocks from 5 cm – 30 cm in diameter across the widest side</td>
</tr>
<tr>
<td>Boulder</td>
<td>B</td>
<td>An area with ≥ 3 boulders (≥30 cm) within 1.5 meters of each other</td>
</tr>
<tr>
<td>Bedrock</td>
<td>BR</td>
<td>An area predominated by solid limestone bedrock</td>
</tr>
<tr>
<td>Sonar shadow</td>
<td>SS</td>
<td>Dark areas caused by objects blocking sonar beam</td>
</tr>
</tbody>
</table>
Substrate Types

- Boulder
- Sand/Pea Gravel
- Rocky fine
- Bedrock
- Large Woody Debris (LWD)
Accuracy Assessment

• Conducted during low water event

• Focused on 9 km stretch
  • Known location of Shoal Bass spawning sites

• Random selection of polygon centroids
  • 40% of each substrate class
  • At least 3 m from polygon edge

• Visual inspection of substrate
Accuracy Assessment

Completed by:
• Kayaking
• Wading
• Diving
Table 2: Standard error matrix and associated statistics for the study area’s substrate map classification. S: Sand, B: Boulder, BR: Bedrock, RF: Rocky Fine.

<table>
<thead>
<tr>
<th>Classified data</th>
<th>Reference site data (field data)</th>
<th>Row Total</th>
<th>User’s accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>B</td>
<td>BR</td>
</tr>
<tr>
<td>S</td>
<td>15</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>BR</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>RF</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Column total</td>
<td>20</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Producer’s accuracy</td>
<td>75%</td>
<td>96%</td>
<td>36%</td>
</tr>
</tbody>
</table>

Bedrock?
- Challenging - Possible shift in sand
  - Length of time
  - Thin layer of sand covering
Other Issues to Consider

• Width
  – One-pass approach – feasible in rivers up to 100m wide (53 m/side) (to maintain resolution)
  – For wider rivers, use multiple passes

• Navigation issues
  – Sharp turns = Image distortion

• Non-penetrating
  – Islands, bridge abutments, sandbars = barriers

• Multiple passes
  – Side channels/Braids/Width

• Depth
  – Too Shallow (< 3 ft) = poor imaging, lack of bank
  – Too deep = decreased image resolution and increased distortion

• Water Column Debris

Using Multiple Passes

Water Column Debris

• First high water events
• Leaf drop
• Wake upstream

Lessons Learned

• Identify substrate classes BEFORE map production.

• Determine Minimum mapping unit

• Have clear (and agreed upon) definitions for each class.

• Consider hierarchical schemes – can later be collapsed into fewer/more classes.
Conclusions

• Provides a unique, rapid, and flexible means to visualize and characterize the underwater environment at the landscape scale.

• This method can be used to fill critical information gaps regarding aquatic habitats and provide a means to monitor these habitats.

• Quantify the distribution and extent of habitat
• Investigate terrestrial-aquatic linkages
• Study patterns of habitat use by resident organisms
• Monitor change over time
  • Habitat monitoring
  • Tracking restoration efforts
Spawning Sites
Questions

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