Identifying Zebra Mussel Distribution in the Hudson River Estuary Using High-Resolution Geophysical Data

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ABSTRACT

Zebra mussels (*Dreissena polymorpha*), an invasive species, have fluorished and continue to spread in lakes and rivers of the northeast U.S. since their 1980s introduction. Documented effects, including declining phyto- and zooplankton and dissolved oxygen, increasing benthic primary production and water clarity, and damage to water intakes, reveal that this species plays an important role in ecosystems. Studies show that zebra mussel distributions change through time, influenced by sediment properties as well as biological and chemical parameters. In the Hudson River Estuary, a dataset including multibeam bathymetry, sidescan sonar, subbottom profiles, and over 1,000 sediment cores and grabs, acquired as part of the Hudson River Benthic Mapping Project funded by the New York State Dept. of Environmental Conservation, allows us to characterize existing zebra mussel habitats. We identify zebra mussels from the northern extent of our study at the Troy Dam south to Croton Point, where summer salinity range is 10-13 ppt. Zebra mussels primarily colonize coarse-grained substrates, but are rarely found in depositional or dynamic areas where we find mobile sediment waves. We use our process-based analysis of the riverbed that incorporates geophysical data with sediment samples and GIS software to map substrates threatened by future colonization, providing a useful tool for estuary managers.

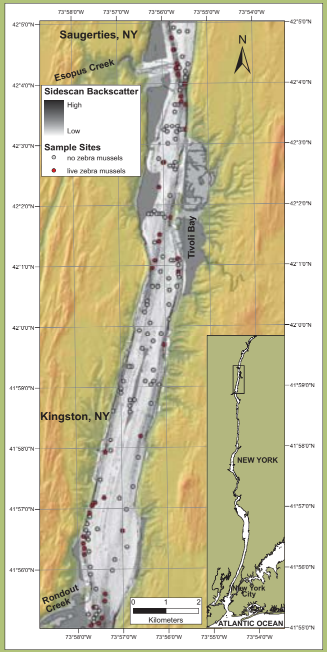

Figure 1. Basemap of the Kingston-Saugerties area of the Hudson River Estuary, showing 100kHz sidescan sonar data. Grab sample sites are shown as circles; red circles indicate live zebra mussels, gray circles indicate no living zebra mussels. Note the presence of live zebra mussels in areas of high sidescan backscatter.

KINGSTON-SAUGERTIES AREA

In the Kingston-Saugerties stretch of the estuary, we use ArcGIS software to create a Geographic Information System (GIS) that incorporates sidescan sonar data and multibeam bathymetry with sediment samples, including grain size information and descriptive characteristics for each sample. GIS systems offer many possibilities to display and compare data and provide a valuable environment for detailed interpretation of our high-resolution data. We produce maps of sediment type by incorporating point samples and associated grain size information with sidescan sonar data (Fig. 1, 2). Using all available data, we develop maps of process-based sedimentary environment, classifying the estuary bottom as depositional, erosional/nondepositional, or dynamic (Fig. 3). We use a similar method and ArcGIS analysis tools to investigate the distribution of zebra mussels in the Kingston-Saugerties area.

Using ArcGIS Spatial Analyst, we can analyze all data types to determine which parameters are most often associated with the presence of zebra mussels in this region of the estuary. We combine sediment type and environment maps to generate polygon coverage of the area and overlay point sample data, with zebra mussel presence/absence information for each point (Fig. 4, 5). We join this with sidescan sonar mosaics and multibeam bathymetry maps. For each sample site, we now have information from all data types: presence/absence of zebra mussels, distance from shore, water depth, mean sidescan value for 20m radius around each point, dominant sediment type and sedimentary environment (Table 1).

Sample ID	Zebra mussels	Dist. to shore (m)	Water depth (m)	Mean sidescan	Sed. Type	Sed. Environment
LW3-G31	0	343.13580515300	-6.30654001236	215.57099914551	muddy sand	Dynamic - waves
LW3-G32	0	437.85240295200	-10.68900012970	181.80099487305	sand	Dynamic - waves
LW3-G33	1	171.38350073100	-18.10519981384	171.66600036621	sand	Dynamic - scour
LW3-G34	1	84.64399342630	-18.82419967651	109.48600006104	muddy sand	Dynamic - scour
LW3-G35	1	401.55286750200	-15.47239971161	100.92099761963	gravelly sand	Dynamic - debris
LW3-G36	0	432.31422187100	-12.63389968872	135.91000366211	gravelly sand	Dynamic - waves
LW3-G37	1	242.33025107400	-10.74740028381	150.84800720215	gravelly sand	Dynamic - debris

Table 1. Example showing the results of combining the point sample data and shoreline polygon (Fig. 4) with sidescan sonar (Fig. 1), multibeam bathymetry, and sediment type and environment polygon data (Fig. 5). Each sample site is now associated with a specific set of attributes from all data types.

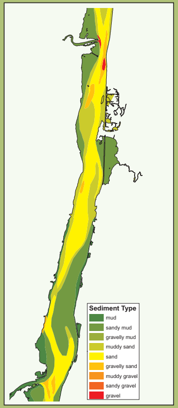

Figure 2. Sediment type interpretation for the Kingston to Saugerties, NY stretch, distinguished by combining grain size analyses from >150 grab samples and core tops and sidescan sonar data (Fig. 1).

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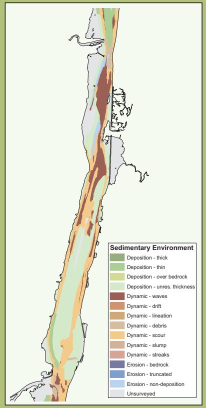

Figure 3. Process-based sediment environment interpretation of the Kingston-Saugerties area. We sorted the different processes into three major classes: depositional, erosional, and dynamic. Within each class, sub-classes define the details of the dominant process.

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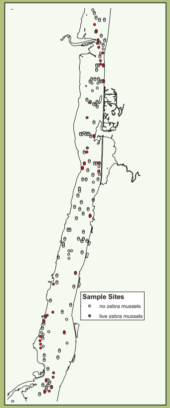

Figure 4. Grab sample sites in the Kingston-Saugerties area. Red circles indicate sites where live zebra mussels were found; gray circles, sites where live zebra mussels were absent.

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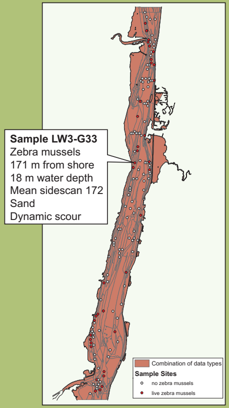

Figure 5. Polygons resulting from the combination of sediment type and sedimentary environment data overlain with samples sites using ArcGIS. Each polygon has a unique ID and a set of attributes contributed by both the sediment type map (Fig. 2) and the sedimentary environment map (Fig. 3).

SUMMARY OF KEY RESULTS

- Zebra mussels are most often found in areas of coarser grain size, where the dominant sediment type is sand or gravel.
- More than 80% of live zebra mussels in the Kingston-Saugerties area are found in dynamic sedimentary environments, particularly areas of debris (potential dump sites) and scour (moderate to high backscatter, rough surface in bathymetry).
- Live zebra mussels are rarely found in areas where sediment waves are imaged (dynamic waves class), although fragments of zebra mussels shells are found.
- Where live zebra mussels are found in muddy sediments, they are always classified as regions of dynamic scour in the Kingston-Saugerties area.
- Although live zebra mussels are often imaged in areas of high sidescan backscatter, there is no statistical correlation between backscatter value and presence of zebra mussels in our data for the Kingston-Saugerties area.
- In the Kingston-Saugerties area, there is no correlation between zebra mussel presence and water depth or distance to shoreline.

FUTURE DIRECTIONS

- Explore correlations between live zebra mussels and estuary morphology, distance from nearest tributary, mean salinity, and hydrographic parameters.
- Incorporate zebra mussel sampling data from 6-7 additional areas in the estuary to better constrain conditions favorable to zebra mussels.
- Extrapolate critical parameters to whole estuary to map substrates suitable for zebra mussel colonization.
- Consider extent of suitable substrate that falls in saline areas, which may be vulnerable to colonization during wet years or even periods of high river flow (e.g. floods, spring freshet).

ACKNOWLEDGEMENTS

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OTHER AREAS OF HUDSON RIVER ESTUARY

The Hudson River Benthic Mapping Project includes geophysical and sediment sampling data for the entire Hudson River Estuary, from the New York Harbor to the Troy Dam. We find zebra mussels in most of the freshwater areas of the system. Although these areas have not yet been completely analyzed with respect to zebra mussels, we have developed sediment type and environment maps and compared visually with point samples. In the New Baltimore and Stockport Flats areas to the north, zebra mussel presence often coincides with areas of high sidescan backscatter (Fig. 6, 7). Further south in Newburgh Bay, we find live zebra mussels on coarse deposits that may be associated with tributary input (Fig. 8) and in dynamic areas where we believe the estuary floor is influenced by the Newburgh-Beacon bridges (Fig. 9).

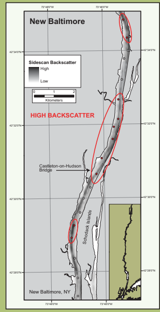

Figure 6. Sidescan sonar mosaic of the New Baltimore area in the northern estuary. Red circles indicate the presence of live zebra mussels; gray circles indicate their absence. Zebra mussels are commonly found in high backscatter areas, which may correspond to harder estuary floor, coarser grained deposits, or highly dynamic locations.

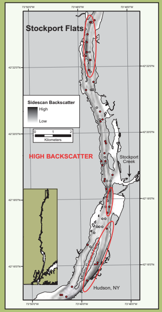

Figure 7. Sidescan sonar mosaic of the Stockport Flats area in the northern estuary. Red circles indicate the presence of live zebra mussels; gray circles indicate their absence. Zebra mussels are often found in areas of high backscatter, specifically along the main channel in this region.

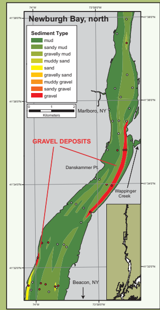

Figure 8. Sediment map of north Newburgh Bay, based on the combination of grab and core samples and sidescan sonar data. Red circles indicate the presence of live zebra mussels; gray circles indicate their absence. In this mainly muddy area, live zebra mussels are found on coarse deposits (gravel lags, tributary deposits).

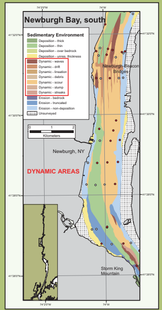

Figure 9. Sedimentary environment map of south Newburgh Bay, based on all available data. Red circles indicate the presence of live zebra mussels; gray circles indicate their absence. Live zebra mussels are found near the Newburgh-Beacon bridges, where the estuary bottom is dominated by dynamic drifts and scour.