Geomorphometric Indicators of Tidal Marsh Condition in Plum Island Estuary

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EMAP Symposium 2004
Newport, RI
4 May 2004

Intertidal Marshes as Critical Landscape Components

- Major source of organic matter fueling commercial and recreation fisheries
- Valuable habitat providing refuge for larval and juvenile organisms from predators
- Sink for high nutrient loads from human-dominated watersheds
- Buffer for urban and developed upland environments from catastrophic storms
- Aesthetically pleasing environment that affects real estate value and social systems

The Issues

- Natural forces and human activities in the coastal zone are contributing to the degradation and loss of critical tidal marsh habitat in estuaries
  - sea level rise
  - disruption of sediment supply
  - nutrient enrichment
  - altered hydrology and canaling
- The processes contributing to marsh degradation and loss are complex and include:
  - sedimentation
  - marsh plant production
  - peat accumulation and decomposition
  - erosion
  - ponding
  - marsh plant community shifts

Research Organization

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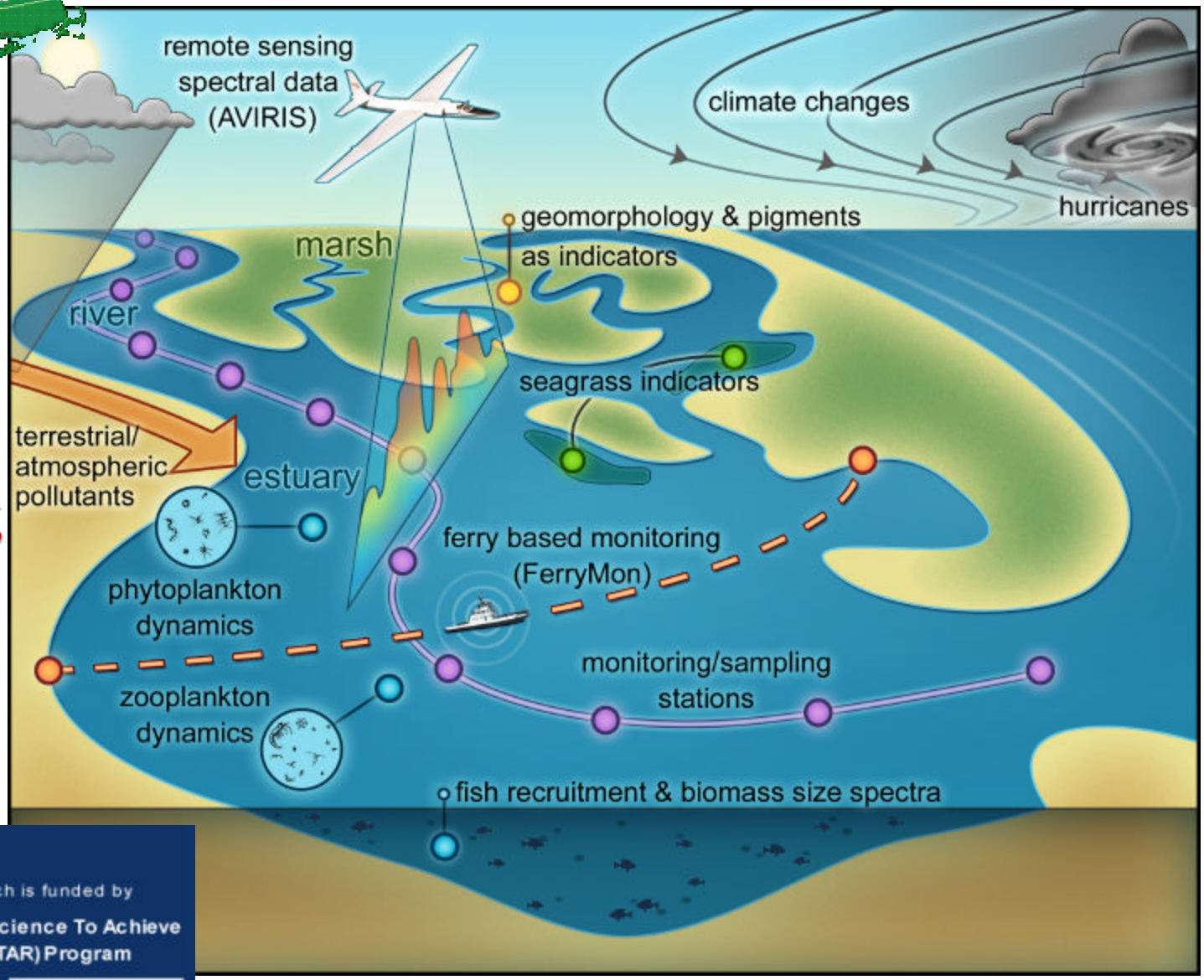
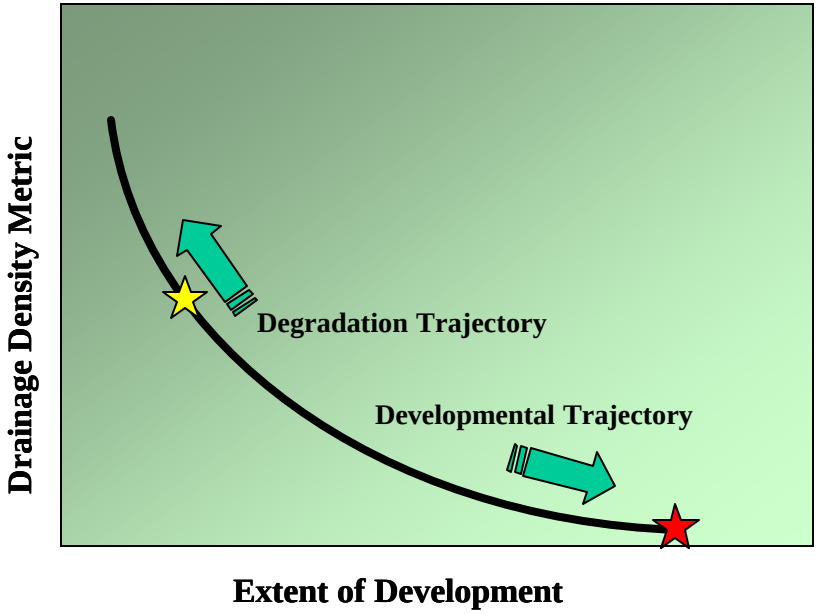


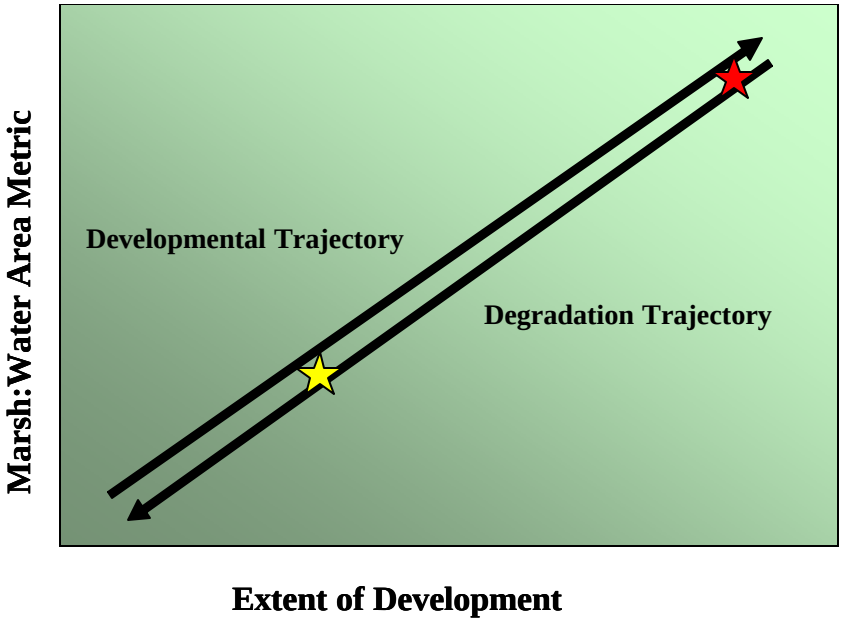
This research is funded by
U.S. EPA - Science To Achieve
Results (STAR) Program
Grant # 82667701

Research Goals

- Develop a suite of geomorphic indicators of intertidal marsh condition and value that can be applied coastwide
- Seek indicators that:
  - measure the magnitude of marsh development relative to maximum potential development
  - identify whether the marsh is in a developmental or degradative phase
  - ascertain the value of marsh from the perspective of 1) storm buffering, 2) habitat, and 3) sink/source strength of atmospheric CO_2
  - offer landscape, as well as site, information when assigning priorities and developing strategies for wetland conservation and restoration efforts

Hypothetical Indicator Trajectories





Storm Buffer Optimum - ★

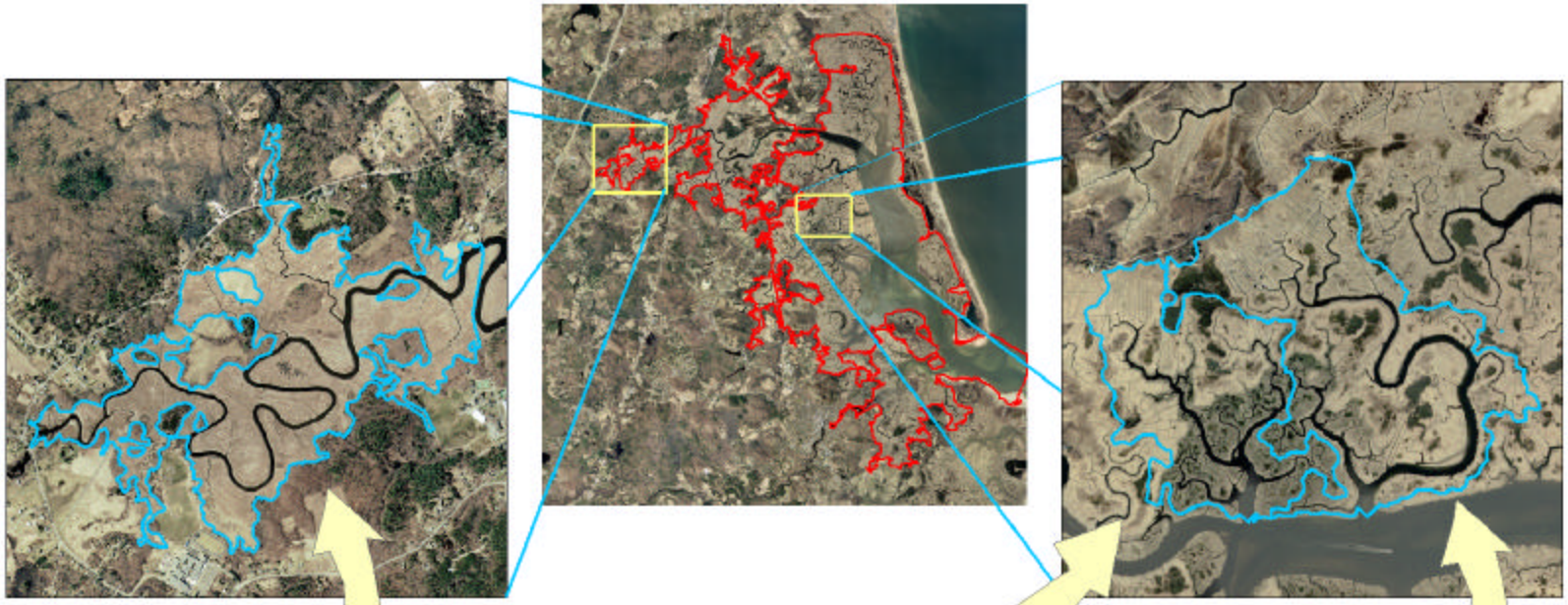
Habitat or CO_2 Sequestration Optimum - ★

Approach for This Study

- Selected regions in Plum Island Estuary marshes in northeastern Massachusetts, the site of an NSF Long-term Ecological Research (LTER) program, along gradients of salinity, sediment supply, vegetation community, and human impact
- Digitized tidal channels and mosquito ditches
  - Spring 2001 color orthophotography (MassGIS)
  - Wetlands cover data developed for the MA Department of Environmental Protection (DEP) Wetlands Conservancy Program (WCP) as starting point
- Generated distance from creek surface to use as a proxy for actual topographic surface
- Created basins from distance surface
- Generated centerline channel networks
- Calculated geomorphometric measures and related to selected regions

Study Locations

Plum Island Estuary



Upper Parker River

Healthy marshes
Flooded irregularly
Low salinity
Typha species and Spartina patens
High productivity
Few creeks
Very few ponds
Extensive ditch network

Shad Creek

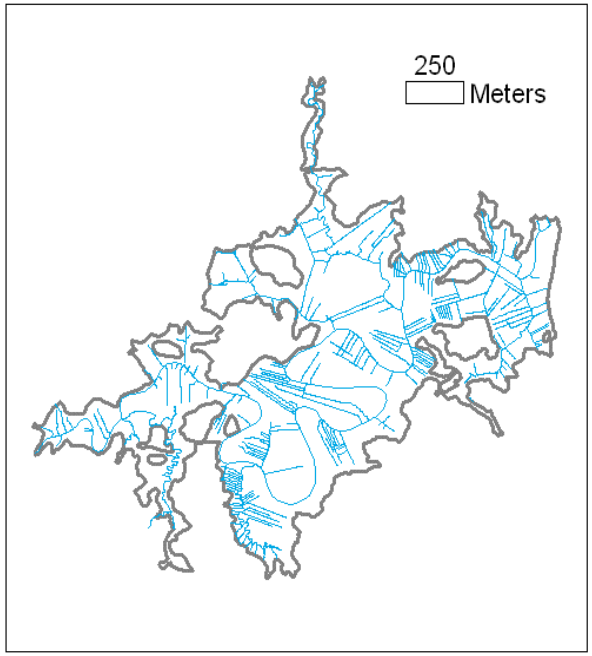
Degrading marshes
Flooded regulary
Moderate salinity
High sedimentation rates
Spartina alterniflora and S. patens
Extensive creek network
Extensive ponding
Some ditches

Club Head Creek

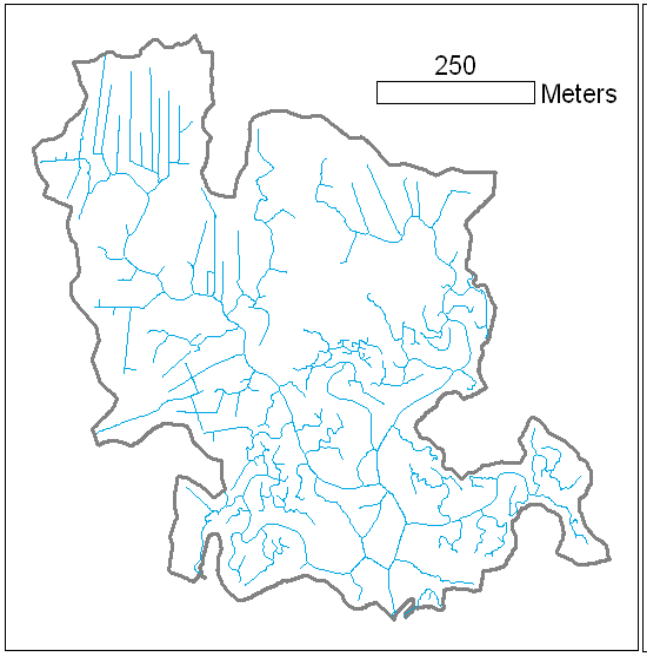
Degrading marshes
Flooded regulary
Moderate salinity
Lower sedimentation rates
Spartina patens with some S. alterniflora
High productivity
Broad creek network
Large expanses of ponds
Some ditches

Channel Networks

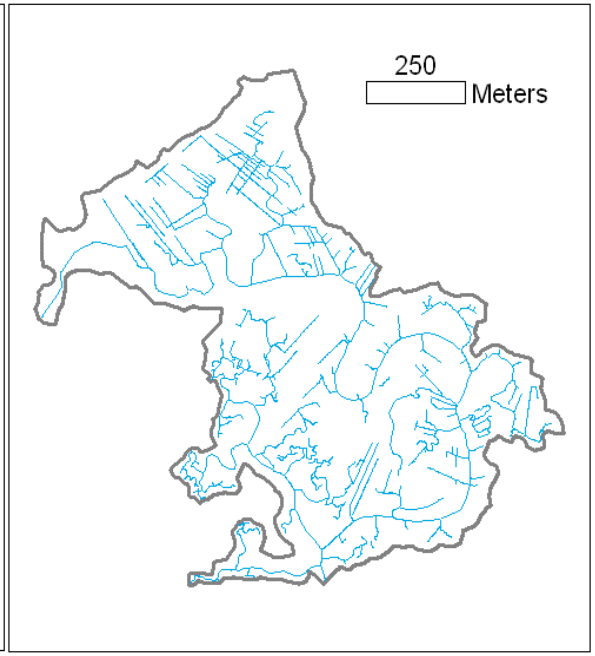
Upper Parker River



Shad Creek



Club Head Creek

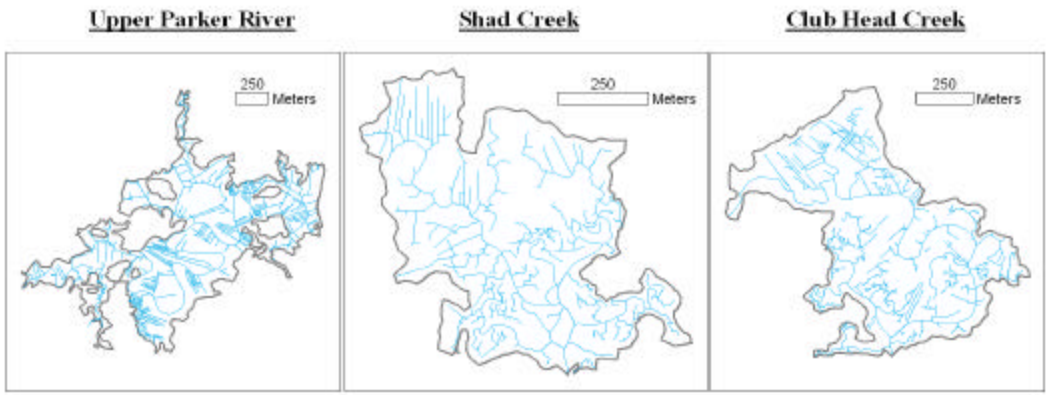


Geomorphometric Measures

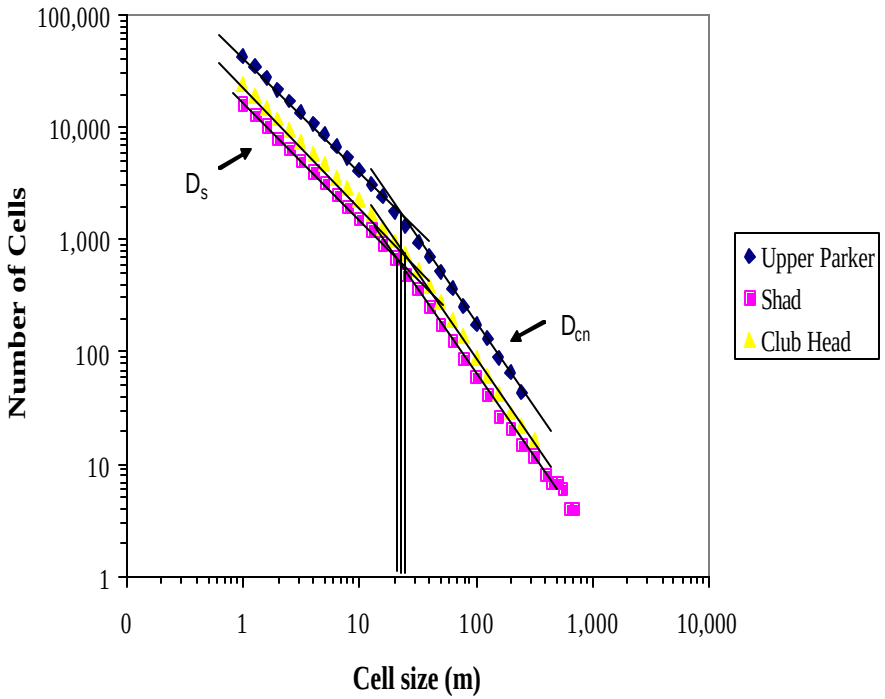
- Drainage Density:
  D_d = Total Channel Length/Basin Area
- Constant of Channel Maintenance:
  $C = 1/D_d$
- Length of Overland Flow:
  $l_o = 1/(2D_d)$
- Sinuosity:
  P = Channel Segment Length/Segment Straight Line Distance
- Fractal Dimensions for individual streams, channel network, and branching structure:
  D_s = negative slope of regression of log(box count) on log(grid resolution) for fine scales
  D_{cn} = negative slope of regression of log(box count) on log(grid resolution) for broad scales
  $D_b = D_{cn}/D_s$ (related to $\log R_b/\log R_l$)(after Helmlinger et al. 1993)

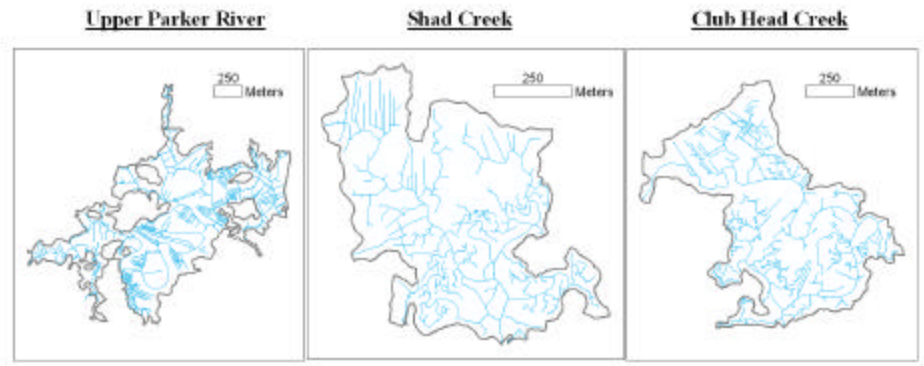
Classical Measures

Basin Name	Basin Area (ha)	Total Length (m)	D_d (m/ha)	C (sqm/m)	l_o (m)	P mean	P range
Upper Parker	143.25	34,181.6	*238.62*	**41.91**	**20.95**	*1.063*	*1.927*
Shad	44.09	13,104.8	**297.22**	*33.65*	*16.82*	**1.129**	3.325
Club Head	72.85	18,560.1	254.77	39.25	19.63	1.103	**3.536**



Fractal Dimensions





Basin Name	D_s	D_{cn}	D_b	Intersection (m)
Upper Parker	1.016	*1.577*	*1.552*	22.54
Shad	*1.012*	1.609	1.590	*20.46*
Club Head	**1.019**	**1.648**	**1.617**	**24.31**

Summary

- While more data and work are needed, geomorphometric indicators hold promise in describing tidal marshes and their condition
- Classical measures are applicable and provide foundation for assessing areas, establishing management priorities and targets, and monitoring status or restoration progress
  - D_d as indicator of landscape dissection and as surrogate for edge
  - C as integrator of water level and sedimentation changes
  - l_o as reflection of available nekton habitat
  - P as indicator of variable water velocity and varied edge habitat
- Fractal dimension analysis seems to provide additional and multiple characteristics
  - network pattern and distribution
  - sinuosity
  - channel support area
  - underlying processes, scaling, and observation limits

Acknowledgments

- Plum Island Ecosystems Long-Term Ecological Research (PIE LTER) Project
- Massachusetts Office of Geographic and Environmental Information (MassGIS)
- Thomas Millette, Chris Hayward, and students of the GeoProcessing Laboratory (GPL) at Mount Holyoke College
- Sergio Fagherazzi at Florida State University
- David Tarboton at Utah State University for TauDEM toolbar
- Dan Rathert at Resource Data Inc. for sinuousity tool

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R828677C003

This research has been supported by a grant from the US Environmental Protection Agency's Science to Achieve Results (STAR) Estuarine and Great Lakes (EaGLe) Coastal Program.

Plans

- Calculate other measures:
  - number and mean length of terminal tributaries
  - mean area of terminal tributary basins
  - sinuosity of terminal tributaries for fractal comparison
  - edge length and edge density
  - number, density, and distribution of ponds and pannes
- Field checking and complete mapping
- Analyze entire Plum Island Estuary
- Run metrics on North Inlet, SC networks and compare
- Develop automated methods based on remote sensing to enable application of indicators to other systems in US coastal zone
- Interact with Massachusetts resource managers and USEPA/EMAP and AED personnel