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Bed erodibility as a function of sediment properties and environmental conditions within the York River Estuary

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Bed erodibility as a function of sediment properties and environmental conditions within the York River Estuary

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CERF Monday Nov. 7th  8:45am
Motivation

NSF MUDBED Project (Multi-disciplinary Benthic Exchange Dynamics)
Understanding fine sediment transport is critical to managing coastal water quality and ecological health, and to understanding coastal ecology, chemical fluxes and the geological record.

What are the key differences in the bed and/or hydrodynamics for low versus high erodibility cores?

Erodibility and settling velocity are difficult to predict because physical and biological effects fundamentally impact them over short scales and physical and feedback on each other.
York River

- Characterized by:
  - Main channel ~ 10 m
  - Secondary channel ~ 5 m
  - Tidal currents ~ 1 m s⁻¹
- ETM located at West Point
- STM found seasonally at Clay Bank

Physical-Biological Gradient:

- In the middle to upper York River estuary, disturbance by sediment transport reduces macrobenthic activity and sediment layering is often preserved.
- In the lower York and neighboring Chesapeake Bay, layering is often destroyed by bioturbation.
York River Conceptual Model

- After high river flow
- Stratified
- Sediment flux convergence
- STM
- High erodibility

Wetter in Spring

Drier in Summer

Dickhudt et al, 2009
Objectives

1. Observe the transition between periods of high and low river flow

2. Assess the role of spring and neap tidal currents on the erodibility of cohesive sediments

3. Distinguish sediment bed properties (including particle types) to decipher controls on bed erodibility
Spring vs. Neap

Spring Tide

- Larger tidal ranges
- Higher current velocities
- Increased water column mixing
- Resuspension of bottom sediments
- Less time for bed consolidation
- Easily erodible material

Neap Tide

- Small Tidal Range
- Decreased current velocities
- Minimal water column mixing
- Decreased bottom shear stresses
- More time for bed consolidation
- Less erodible material
Methods

Sediment sampling cruises were taken to coincide with spring/neap in 2010
- Spring ~ 3 samples
- Neap ~ 2 samples

Samples collected using a Gomex Box Core
- Sliced at 1 cm intervals
- Sampled for
  - water content
  - grain size
  - resilient pellet presence and concentration
  - Be 7 radioisotope activity
- Addition samples were collected for:
  - Gust Microcosm Erodibility
    - X-ray analysis
    - Core logger
Capturing the transition

York River Estuary Discharge

Discharge (m$^3$/sec)

Date
Environmental Conditions ~ Prior to sampling

River flow (m$^3$/s)

Salinity in main channel near coring site (PSU)

TSS in main channel near coring site (mg/L)

(Data sources: USGS & EPA monitoring)

Month in 2010

Discharge occurs in winter/early spring

Salinity stratification develops (lagging discharge)

Stratification favors:
- convergence of sediment flocs
- net deposition
- lower erodibility
- higher TSS

Near surface

1 m above bottom

Winter/early spring condition

Environmental Conditions ~ Prior to sampling

Discharge occurs in winter/early spring

Salinity stratification develops (lagging discharge)

Stratification favors:
- convergence of sediment flocs
- net deposition
- lower erodibility
- higher TSS

Near surface

1 m above bottom

Winter/early spring condition
Environmental Conditions ~ During Sampling

Study Focus: ~1 month after river discharge peak

Salinity stratification significantly decreases

Leads to transition from convergence to net erosion of flocs

Coring study during late spring transition period

River flow (m³/s)

Salinity in main channel near coring site (PSU)

TSS in main channel near coring site (mg/L)

(Data sources: USGS & EPA monitoring)
1) Expect general decrease in erodibility with time due to seasonal net erosion and divergent floc transport.

![Graph showing a linear trend with two peaks and troughs indicating tidal range fluctuations.](image)

Gust eroded mass (kg/m$^2$) at 0.2 Pa

Tidal range (m)

Boxes are tidal range for previous 5 days

$r = -0.51$

$r = +0.75$

2) Also expect temporary periods of increased bed disturbance and shorter consolidation time when tides are stronger. I.e., just after spring tide $\Rightarrow$ expect higher erodibility; just after neap tide $\Rightarrow$ expect lower erodibility.
Multiple Regression combining seasonal discharge and tides

Observed eroded mass at 0.2 Pa

\[ r = +0.89 \]
\[ r^2 = 0.79 \]

\[ C_1 - C_2 \times \text{Time} \] (net erosion effect)
\[ + C_3 \times \text{Tide Range} \] (lower consolidation effect)
Eroded Mass vs. Percentages of Various Sediment Components

(a) Water (% by vol.)

(b) Sand (% dry wgt.)

(c) Organics (% dry wgt.)

(d) Mud (% dry wgt.)

(e) Mud matrix % solids

(f) Pellets (% dry wgt.)

Only significant 1-component regression
Pellet abundance vs. time and tidal range

Pellet abundance increases with time and decreases with tide range.
Two main factors affecting bed erodibility

- The convergence and divergence of sediment due to stratification
- The spring-neap effect on tidal velocity

Environmental factor analysis

- Erodibility was negatively correlated to lagged decreases in river discharge and therefore stratification
- Erodibility was positively correlated to previous changes in tidal range
  - Spring Tide ~ Increases erosion potential
  - Neap Tide ~ Decreases erosion potential
- The combination of the two factors leads to a correlation of .89

Sediment Bed Properties and Comparisons

- No classically expected bed parameters directly affect bed erodibility
- EXCEPT...the abundance of resilient fecal pellets

Resilient Fecal Pellets may be serving as a proxy for other parameters influencing the area

- Bed armoring
- Cohesion
- Winnowing of fines
Thank you!

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