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Muddy Waters: Monitoring of Sediment Properties on Bay of Fundy Mudflats Post Causeway Modification

J. Murray[1], K. Haralampides[2], M. Barbeau[3]
[1]Knight Piésold, Vancouver, BC Canada
[2]Department of Civil Engineering, University of New Brunswick, Fredericton, NB Canada
[3]Department of Biology, University of New Brunswick, Fredericton, NB Canada

Abstract: The Petitcodiac River causeway, situated in New Brunswick between the cities of Moncton and Riverview, was constructed in 1968, stopping the flow of sediment-laden tidal water and halting access for spawning fish. A complex process has begun to remove the causeway to restore the Petitcodiac River bringing it closer to its pre-causeway condition; the first stage was to open the causeway gates to allow free-flow of tidal water. The effects of the change in hydraulics have been hypothesized, but due to the nature of the cohesive sediment there is still some uncertainty about the fate of the flushed sediment, and the impacts it may have on downstream mudflat ecosystems in the upper Bay of Fundy. Two mudflats downstream of the Petitcodiac River causeway, Grande-Anse (NB) and Daniel's Flats (NB), were monitored, as well as two reference sites, Peck's Cove (NB) and Minudie (NS). Over the course of one year, transects were repeatedly visited and the erosion threshold and erosion rate of the mud surface was measured using the Benthic Environment Assessment Sediment Tool (BEAST), as well as several other measures of sediment and biological properties such as diatom concentration, *Corophium volutator* density, mud penetrability, average particle size, and moisture and organic content at several depths. A total of eight field visits were made, spanning from pre-causeway gate opening to one year post gate opening. Preliminary results suggest that there were no detectable changes in the measured mudflat properties at the potentially impacted sites, though monitoring continues.

1 Introduction

1.1 Bay of Fundy

The upper Bay of Fundy in eastern Canada boasts some of the highest tides on earth, often 13 m in height, that cause erosion of the shale and siltstone cliffs outlining much of the shoreline (Desplanque and Mossman 2004). Large deposits of cohesive silt and clay form expansive, highly-productive mudflats that can span more than 1000 ha (Percy et al. 1997). It is estimated that that 50-95% of the world's Semi-Palmated Sandpipers (*Calidris pusilla*) make the mudflats their refuelling stop every year in July/August where they double their mass before continuing south (Hicklin 1987). As such, this area has been designated as part of the Western Hemisphere Shorebird Reserve Network (Shepherd and Boates 1999).

The visiting sandpipers feed mainly on mudshrimp (*Corophium volutator*), a tube-dwelling amphipod found near the mudflat surface (McCurdy 2005). *Corophium* range in length from 1mm when first hatched, to 10mm as an adult. They dig U-shaped burrows with two openings at the sediment surface, approximately 7cm deep, depending on the size of the individual. Every one or two days, *Corophium* will create new burrows, which are compacted and lined with an adhesive secretion (Gerdol and Hughes 1994). They are known to feed on diatoms, which are unicellular sediment-stabilizing organisms that grow in mats on the sediment surface and are believed to create a stabilizing effect on sediment against the erosive forces of the tides due to their use of a mucous that binds sediment grains together (Grant et al. 1986). There are conflicting results as to whether *Corophium* have a net negative or positive effect on sediment stability. Predicting the erodibility of this fine, cohesive sediment complicated by its dynamic interactions with *Corophium* and other biota found in the upper Bay of Fundy. The stability and longevity of the mudflats is paramount for the complex ecosystem that is vulnerable to sea level rise and to anthropogenic activity in the area, including the modification of an upstream tidal barrier on the Petitcodiac River Estuary.

1.2 Riverview Causeway

In 1968, a causeway (with control structure) was constructed across the estuarine Petitcodiac River between Riverview and Moncton NB, which, over time "has impacted physical processes including tidal exchange and sediment transport, and a variety of ecosystem functions including fish passage in the Petitcodiac River" (AMEC 2005). With approximately 2 million m^3yr^{-1} of sediment infilling, the channel depth and width has been reduced, and a sediment plug has been deposited into the headpond. Now, four decades later, plans are in effect to restore the Petitcodiac River, starting with the opening of all five of the control structure's gates on 14 April 2010, with future plans to construct a bridge span to replace the centre of the causeway. The resulting hydrodynamics and subsequent channel morphological changes have been estimated, but due to the complex nature of the cohesive material in the area, there remained some uncertainty about the sediment fate and consequences for the downstream mudflats.

2 Methods and Results

A study investigating the potential effects of the opening of the causeway gates on downstream mudflat sediment characteristics in the short term was undertaken; concurrent biological research was also conducted that examined ecosystem dynamics. Sampling occurred immediately before and after the gates were opened, and continued in May through September 2010, and once again in April 2011. Sediment stability (erosion threshold/rate) was measured, as well as several factors related to stability such as water content, organic content, diatom and *Corophium* densities and particle size distributions.

2.1 Study Sites

Two sites with impact potential were chosen at opposite sides of Shepody Bay, near the causeway: Daniel's Flats (DF) and Grande Anse (GA). Two reference sites were chosen away from predicted impacts, but still in the same tidal area: Peck's Cove (PC) and Minudie (MN). The reference sites are in Cumberland Basin, where they would still experience the same tidal effects as Shepody Bay but fewer, if any, of the potential impacts of sediment from the opening of the causeway gates.

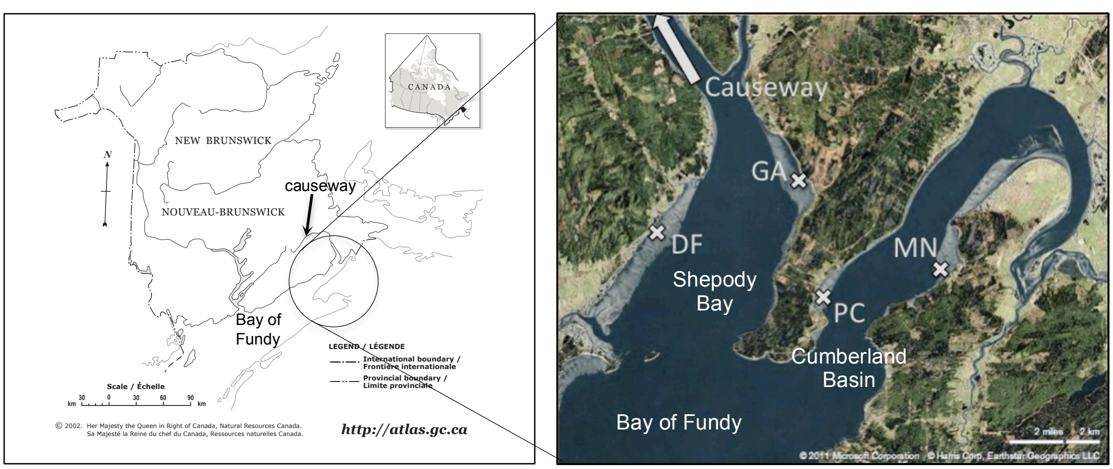


Figure 1: Study site overview and sampling locations (atlas.gc.ca, Earthstar Geographics LLC)

2.2 Benthic Environmental Assessment Sediment Tool

To estimate the erosion thresholds and rates in the field, a Benthic Environment Assessment Sediment Tool ("the BEAST") (Grant and Walker, in press) was used. The BEAST uses the controlled frequency of oscillation of a perforated disc inside of a core chamber to determine quantitative measurements of erosion threshold and erosion rate using a turbidimeter probe fixed inside the core. The perforated disc's oscillation frequency is proportional to a bed shear stress, used to quantify the erosion threshold of a core sample which is signified by a sharp increase in turbidity, known as the transition from Type I erosion (lifting of biofilm and flocs) to Type II erosion (complete breakdown of surface layer). In this study, calibration curves were developed for each of the four sites, at three intervals along the intertidal zone.

2.3 Sample Collection and Processing

At each of the four sites, a transect was delineated and marked by GPS. The transects, ranging from 1.9 to 2.2 km were divided into four zones, each of which were sampled at randomly generated distances during the visits. Samples included one BEAST core, one sediment core (2 cm diameter), two measures of diatom abundance (chlorophyll *a*) and two penetrability tests (dropping a weight from 1m height). The BEAST cores were obtained using 11.4 cm diameter, 50-cm tall Plexiglas tubes that were pressed until approximately 1/3 full into a relatively flat area of sediment surface and dug up before being capped and carried carefully back to shore for processing. The height of the Plexiglas tube was filled with 30 ppt filtered seawater and set into the BEAST unit with the perforated disc set 2 cm from the sediment surface. Oscillation frequency was increased every 2 minutes with turbidity readings being logged every 1 minute.

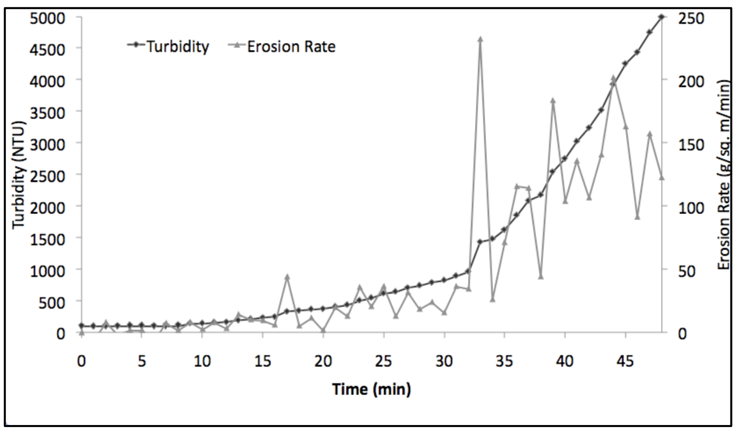
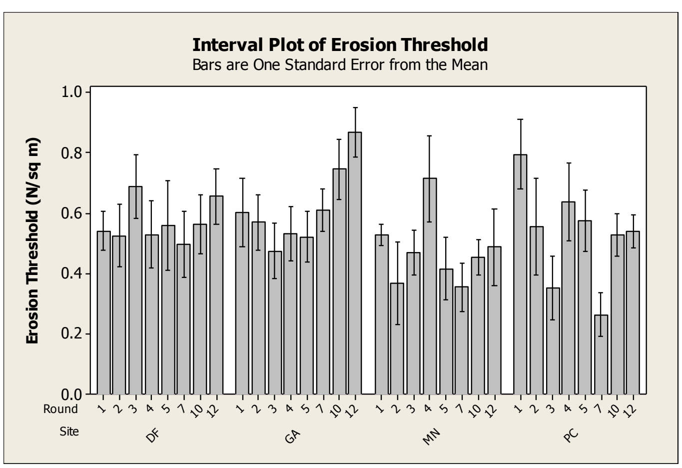


Figure 2: Example plot of BEAST results



Sample Round	Date
1	6-10 Apr '10
GATES OPEN 14 APRIL	
2	12-15 Apr '10
3	23-26 Apr '10
4	12-16 May '10
5	1-4 Jun '10
7	14-18 Jul '10
10	21-30 Sep '10
12	11-14 Apr '11

Figure 3: Interval plot of erosion threshold over study duration

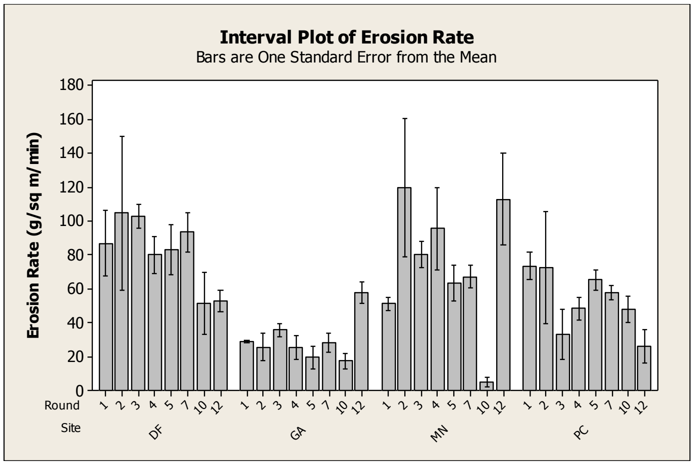


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Figure 4: Interval plot of erosion rate over study duration

The results indicated that the sediment stability characteristics remained unaffected by the change in the upstream hydrodynamic conditions and sediment flux. While there were differences in erosion rates among the various mudflats, they remained constant before and after the opening of the causeway gates, and can be more attributed to the sediment characteristics of the sites themselves. Statistical analyses were run to examine possible correlations between factors affecting erosion, such as particle size distribution, water/organic content, and penetrability, as well as *Corophium* and diatom density. A gradient in biomass was observed over time, but it followed the life cycle patterns of the mudflat biota as expected. Correlations were observed between water content at all depths and penetrability, which affected the erosion rate. Grande Anse, a ‘soupy’ mudflat, was noted to have high water content, high organic content and low Corophium density than the other sites; the erosion threshold is high and rate is low there (indicative of enhanced sediment stability), which is believed to be due to a decreased density of Corophium that are known to feed on diatoms which are sediment strengthening unicellular organisms.

Conclusions

This study was part of a larger project that was looking at ecosystem population dynamics on the upper Bay of Fundy mudflats. Cohesive sediment stability characteristics were unaffected by the modification of the upstream tidal barrier in the one-year following the opening, but the project did further the development of an understanding of the complex Bay of Fundy mudflat ecosystem.

References

AMEC. 2005. *Environmental Impact Assessment Report for the Modifications to the Petitcodiac River Causeway*. AMEC Earth & Environmental, a Division of AMEC Americas Limited Fredericton, NB.

Desplanque, C. and Mossman, D.J. 2004. Tides and their seminal impact on the geology, geography, history, and socio-economics of the Bay of Fundy, eastern Canada, *Atlantic Geology*, 40: 1-130.

Gerdol, V. and Hughes, R.G. 1994. Feeding behaviour and diet of *Corophium volutator* in an estuary in southeastern England. *Marine Ecology Progress Series*, 114: 103-108.

Grant, J., Walker, T.R., Hill, P.S., Lintern, D.G. 2013 in press. BEAST—A portable device for quantification of erosion in natural intact sediment cores, *Methods in Oceanography* ISSN 2211-1220, 10.1016/j.mio.2013.03.001 (http://www.sciencedirect.com/science/article/pii/S2211122013000157)

Grant, J., Bathman, U.V., and Mills, E.L. 1986. The interaction between benthic diatom films and sediment transport. *Estuary Coast and Shelf Science*, 23: 225-238.

Hicklin, P.W. 1987. The migration of shorebirds in the Bay of Fundy. *Wilson Bulletin*, 99: 540-570.

McCurdy, D.G., Forbes, M., Logan, S., Lancaster, D., and Mautner, S.I. 2005. Foraging and impacts by benthic fish on the intertidal amphipod *Corophium volutator*. *Journal Crustacean Biology* 25: 558-564.

Percy, J. A., Wells, P. and Evans A. (Eds). 1997. Bay of Fundy Issues: A Scientific Overview. Workshop Proceedings, Wolfville, NS, Environment Canada: *Atlantic Region Occasional Report #8*, 191 pp.

Shepherd, P.C.F. and Boates, J.S. 1999. Effects of baitworm harvesting on the amphipod *Corophium volutator* and on the semipalmated sandpiper *Calidris pusilla*. *Conservation Biology*, 13: 347-356.