Temporal Dynamics of Microbial Metabolism in a Salt Marsh Tidal Creek

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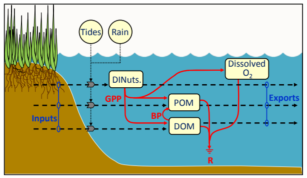
OBJECTIVES:

Tidal creeks represent conduits for organic matter exchange between salt marshes and the coastal ocean. They are also areas of substantial net heterotrophy (total respiration > *in situ* primary production), fueled by organic matter inputs produced by adjacent marshes/uplands. The objective of this study is to quantify the response of microbial metabolism in tidal creeks to tidal, seasonal, and inter-annual variability in the magnitude and form of salt marsh exports. Our focus is on heterotrophic processes, as these are presently poorly quantified for tidal creeks, and to explore the utility of heterotrophic rate measurements to serve as sensitive, quantifiable indicators of ecosystem-level response to environmental change associated with altered inputs to salt marsh tidal creeks.

Conceptual model highlighting linkages between salt marsh input, tidal creek biogeochemistry and organic export to the coastal ocean. Measurements conducted in this study include nutrient, organic matter and dissolved O_2 stocks, and rates of bacterial production (BP) and respiration (R). Gross primary production (GPP) is not routinely measured in this study.



STUDY SITE:

All sampling is conducted at Oyster Landing in Crab Haul Creek, an undeveloped, first-order creek of the North Inlet estuary. This location has been the site of long-term monitoring conducted by the BMFL and NI-WB NERR for more than 20 years.

SAMPLING PROTOCOLS:

Abiotic water quality is conducted continuously at 15-minute intervals by automated data sondes. Water chemistry and rate measurement sampling is conducted on a 20-day frequency. For water chemistry measurements, 13 samples are collected every 2h and 4 min for one complete semidiurnal tidal cycle. For rate measurements, one sample is collected on ebb tide just before slack-low and one sample is collected on flood tide just before slack high.

METHODS:

Microbial Respiration

- $[O_2]$ by automated Winkler titration
- Whole water and <1.2 µm fraction
- 4-8 h incubations at *in situ* temperatures

Bacterial Production

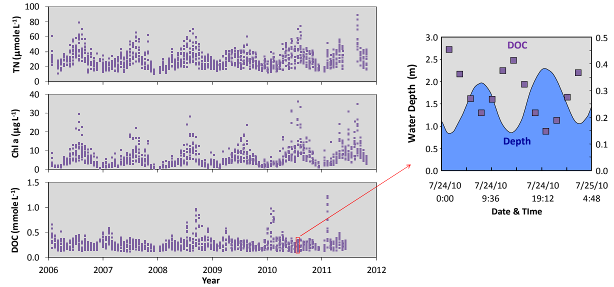
- ^3H leucine incorporation method
- Whole water and <1.2 µm fraction
- 1 h incubations at *in situ* temperatures

Environmental Variables

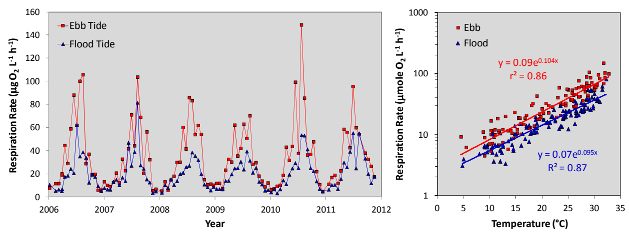
- NH_4, NO_2, NO_3, TN in both whole and GF/F filtered fractions (with DON by difference)
- PO_4, TP in both whole and GF/F filtered fractions (with DOP by difference)
- DOC concentration and DOM optical properties (a_{355} and spectral slope)
- TSS and VSS (by combustion at 450°C)
- Chlorophyll *a*
- Temperature, salinity, pH, turbidity, dissolved oxygen

RESULTS:

1. Most nutrients, as well as Chl *a*, exhibit strong seasonal pattern, although DOC (the largest pool of organic carbon) does not. All variables show pronounced tidal variability, which is often greater than seasonal variability, especially in summer.



2. Microbial respiration exhibits pronounced seasonal cycles, driven largely by a strong exponential relationship with temperature, but ebb tide rates tend to significantly exceed flood tide rates.



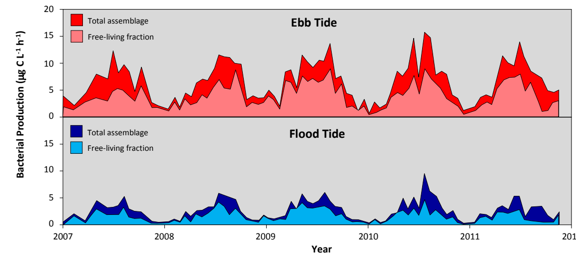
3. Individual environmental parameters do not explain residual variation in respiration vs. temperature relationships. However, Log-transformed Ebb-Flood differences in respiration are positively correlated to log-transformed Ebb-Flood differences in TN, TP, DOC, POM, Chl *a*, and integrated light levels (PAR), although negatively correlated to inorganic N and P concentrations. Differences in tidal range (depth) across sampling dates significantly explains magnitude of Ebb-Flood differences in dissolved constituents, but not particulate constituents.

Nonparametric Correlation Matrix of LN(Ebb) – LN(Flood) Differences
Spearman's ρ values and significance levels

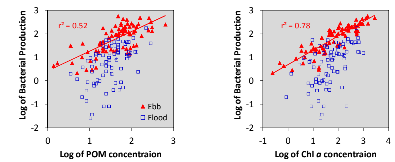
	Depth	PAR	TN	TP	DIN	DIP	DOC	POM	Chl a
Resp.	-0.110	0.458	0.385	0.196	-0.451	-0.344	0.201	0.509	0.644
Depth		0.118	-0.294	-0.333	-0.357	-0.418	-0.349	-0.047	-0.032
PAR			-0.045	-0.111	-0.493	-0.322	0.007	0.223	0.156
TN				0.511	0.123	0.019	0.495	0.508	0.546
TP					0.036	0.021	0.271	0.368	0.390
DIN						0.679	0.297	-0.439	-0.359
DIP							0.188	-0.452	-0.349
DOC								0.039	0.099
POM									0.725

$p < 0.05$ $p < 0.01$ $p < 0.001$

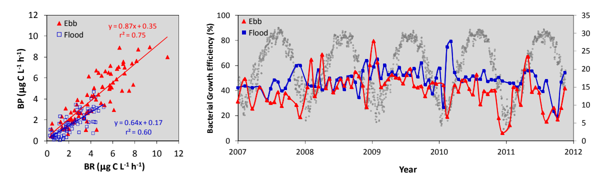
4. Bacterial production (both total and free-living fraction) exhibit the same strong seasonal and tidal patterns as seen with respiration. While a greater proportion of BP occurs in the free-living fraction, rates associated with bacterial attached to POM can be significant during summer periods.



5. Despite their generally similar range in concentrations over ebb and flood tides, rates of bacterial production are more tightly linked to POM and Chl *a* concentrations during ebb tides than during flood tides.



6. Rates of bacterial respiration and production are tightly coupled, such that bacterial growth efficiency is independent of temperature, although its variability is at present poorly understood.



CONCLUSIONS:

Tidal creeks are sites of substantial heterotrophy. This heterotrophy is strongly linked to temperature, with a 2 °C increase in temperature resulting in an ~25 % increase in respiration and associated CO_2 efflux. Pronounced ebb- versus flood-tide differences in respiration and bacterial production indicate the importance of salt marsh exports in fueling tidal creek heterotrophy, although the relationship between exports and metabolism is multifaceted. Particulate organic matter concentrations appear to be an important driver of tidal creek metabolism, however, despite previous studies that indicate net organic matter export from the Crab Haul Creek occurs entirely in dissolved form. Although data analyses are ongoing, study results suggest that measures of bacterial metabolism have promise as a simple yet integrative means of assessing ecosystem-level response to changing environmental conditions and perturbations.