New Hope Creek – longitudinal chemistry and metabolism

Metabolism Variation

Do pools and runs have different metabolism?

What is the spatial variability in magnitude and timing of metabolism and cumulative metabolism?

How does interannual variability compare to spatial

What in stream processes control O2

* What do we expect from physical controls – how do observations differ?
* How much do reach characteristics matter and what are they
* Controls: hydrology, temperature, litterfall, LAI, GPP, geomorph and substrate
* Contingent on template, o2 demand and delivery, geomorphology and hydrology create places that are susceptible and highly resistant to hypoxia

What are the implications for energetic cycling and scaling of metabolism – Hall, fish?

High O2 demand makes it impossible to see productivity

New Hope creek experiences metabolic variation both temporally and spatially. We measured dissolved oxygen in six locations along an eight kilometer longitudinal reach, with three sites in pools three in runs, to determine (1) Do pools and runs differ in their oxygen dynamics and metabolism? (2) Do local channel characteristics influence metabolic dynamics? (3) What is the footprint of metabolism and what is the role of geomorphic structure in determining this? (4) When do pools transition from lotic to lentic? Is this a discrete, state-change or is it a smooth transition?

We found that metabolism varies in space and time along the transect and that spatial variation is not explained by habitat type. All of the sites experience a spring peak in autotrophic and heterotrophic activity. Some of the sites experience a fall heterotropic respiration peak associated with litterfall, while others do not. There is not a fall autotrophic production peak. New hope creek is a low productivity stream compared to the range in the streampulse dataset, the production and respiration numbers fall in the lower quartile except for during the fall respiration peak.

This makes me want to plot some things: A histogram of water residence times - does this cluster around two end points? Or is it an exponential distribution? Is that different for pools and runs? How do I define a reach? the metabolic footprint is traditionally defined as 3v/k, meaning the size of the ecosystem will be changing. I think it would be interesting to look at the residence times in these footprints over time. What does the relationship 3v/k look like over a range of Q? both V and K are positively correlated with Q. Which grows faster? This analysis might belong in the lotic lentic paper I am working on. I should try calculating what each of my sites are based on that one lotic lentic paper that defines using water residence time.

The largest respiration pulse is in upper new hope creek. Is this real? or is this not a clean sensor? I need to look at multiple years of metabolism from NHC and UNHC to see if this pattern holds steady.

What does heterotrophic respiration look like? Is this controlled by local geomporphology? By residence times? The pool vs run comparison fails because these bins are not as discrete as I would like them to be. Many of the runs become pool like at low flow and they also contain the signal from the upstream pools, especially in the case of the wooden bridge site. Is the NHC site really a run? That seems questionable.

Could I use the WB and the WBP sites as a two station metabolism setup? What will this tell me that is different from my current numbers?

So what are the take homes? variation in heterotrophic respiration along a longitudinal transect is driven by mean residence times of water and local bed substrate more than by autotrophic productivity. The range in metabolism paired with the changing size of the metabolic footprint complicate our ability to scale to ecosystem level metabolism. Pools may be a hotspot of metabolism and biogeochemical activity due to long water residence times. However, this same feature causes the footprint of that metabolism to be correspondingly smaller, representing a smaller portion of the whole ecosystem. If we measure rates on an aerial basis, this means that

What does a river look like if you plot mean residence time by distance along the river? This should generally increase with river size, but it will also be punctuated by pool habitats. is this the conceptual framework we need to scale river ecosystems? What does this have to do with Martin's nutrient spiraling in big rivers paper?

Next steps: plot WRT distributions. Plot heterotrophic respiration (vs DOY, vs WRT). Look at interannual variability at UNHC. plot Q vs 3V/K for each of the sites. Maybe do one more big field day where I measure depths and water velocities etc for the whole length of NHC.

Hall metabolism comparison 10/7 moved to separate document

What are three things we can say about the data in comparison to the Hall 1972 study right now?

Hall’s Main findings:

* Dissolved oxygen swings are large, pre-dawn sampling is recommended for regulation
* Metabolism decreases downstream. This is true on an areal basis, though only a little. Volumetric metabolism is inversely proportional to depth => there is more energy available per cubic meter in the headwaters
* Larger fish move upstream, smaller fish move downstream. The net is a mass flux upstream
* Respiration and metabolism peak in the spring
* Storms \*might\* be correlated with high metabolic rates
* Low flow, low oxygen period in the summer. Swings are larger in shallower water.

Major take homes with a 50 years later data comparison:

1. The magnitude of metabolism is similar between both datasets. Metabolism in New Hope Creek hasn’t really changed that much in 50 years despite huge (?) changes in land use and ISC, duke forest development etcetera.
   1. Questions to look at here: What has changed in DF? Have the water temperatures changed? Have the temperature swings changed? Has the discharge changed?
2. Day to day variation in NHC may be as large as seasonal variation.
   1. What does this say about the drivers? Storm control on productivity, dry periods control reaeration.
   2. How does this change our picture of cumulative metabolism? Does this capture a different picture in regards to the energy available to consumers?
   3. Hall’s data may be skewed by one high storm sampling point. Our data suggest that storm metabolism is lower than on other days (check this, in comparison to Hall-sized flood)
3. Spatial variation on a given day may be greater than seasonal variation
4. Fall respiration peak may have grown
   1. Hall didn’t capture a huge het respiration peak like we see, this could be due to:
      1. He missed it:
         1. Interannual variability. This peak isn’t always so big
         2. Spatial variability. This peak is way bigger some places than others
      2. It’s new
         1. Temperature increased
         2. baseflow decreased
         3. OM load increased
         4. More nutrient availability – system was never C limited
5. Depth x productivity relationship on a smaller scale than the entire continuum is controlled by habitat type: ie, pools and runs
   1. This is because residence time of water has increased with lower baseflow. Local geomorphology is king.
6. We are reaching lower DO values.
   1. This could be due to increase in sampling, could be due to more heterotrophic shiz

If we are observing a shift to heterotrophic respiration, what is the implication?

* Geomorphic drivers
* Temperature
* Nutrients
* Connectivity to groundwater

More broadly, what does this mean for streams in the piedmont?

If headwater streams like New Hope Creek are increasing in heterotrophy even under minimal change in surrounding land cover that has broad implications.

What have we learned about NHC that Hall didn’t know?

* If you read through Hall’s paper, what are the new things that we can add to his conclusions?

**Fifty years later: Annual metabolism in NHC reveals a stream that has responded to land use changes and increasing temperature with a shift toward heterotrophy.**

**Introduction**

Ecosystem metabolism is a whole system measurement of energy production and energy cycling. It allows us to quantify when and where resources are available and how they move across landscapes crossing barriers between systems. Primary productivity is a basal energy resource for consumers. Heterotrophic metabolism controls the release of CO2 to the atmosphere and determines the rate and nature of carbon transformations. Its nature determines ecological function and stoichiometery. This metric on a whole system level has allowed us to understand important fluxes in the global carbon cycle and drivers of community and population dynamics.

Metabolism is sensitive to changing global drivers such as warming temperatures and shifting water distributions. Warm temperatures increase the metabolic demand of organisms, and this is seen on whole system levels. Changing water flows alter the magnitude and timing of metabolism. In addition to shifting global drivers, local human impact such as changing land use and altering stream networks through flow impoundments and impervious surface cover lead to altered flow dynamics that impact energetics. Loading of carbon and nutrients can shift the balance of primary productivity and respiration, cascading into trophic cascades, changed stoichiometry and impaired habitats.

Studies have demonstrated that metabolism is temporally variable, with distinct phenologies in different stream types. Annual records of metabolism allow us to understand the timing and cumulative metabolism in a way that snapshots cannot do. We also know that inter-annual variability can be high in some systems. This allows us to understand how metabolism varies in response to drivers that vary year to year. We know that some streams respond to years drought years with a decrease in primary productivity. Other streams are impacted on high flow years. Studies in response to human alteration show metabolic recovery after removal of pollution.

Because our ability to get these time series is pretty new, we don't have a lot of info on long term change in metabolism in response to natural and anthropogenic shifts in drivers. Over long time periods, do streams respond consistently to the shifts we observe between sites and from one year to the next? How stable is a streams metabolic regime over long periods of time?

New hope creek is the site of the first annual metabolism study. We revisit it 50 years later to examine how land use, climate, and forest management have changed metabolic processes. Three years of data from 1968-1970 show a stream xx. Over the intervening 50 years, increasing temperatures, a shift toward a flashier hydrologic regime with lower baseflows, and a restoration of a forested riparian buffer have combined to shift the stream toward more heterotrophy.

Chemical discontinuity and connectivity

Incredible temporal variation in how disconnected they are. Patch transfer shifting from internal to external

Seasonal and spatial patterns in thermal and oxygen regimes in a piedmont river

What are the scales of discontinuities in raw data. Gas vs aqueous

Connected at times other times disconnected.

Not ephemeral, just a slow moving normal stream

Do all the data separate together? When is connectivity lost. How do constituents covary

* Make NMDS or PCA like J’s chemical flashiness paper
* Are there high leverage solutes? Ones that pull or drive?

How does variance within a watershed compare to between watersheds.

What are calculated gas fluxes. Is this even relevant.

What is the ratio of WRT during high flow between sites and during low flow?

* Which solutes respond most strongly to residence time?
* What about for all the other stuff
* Do some things disconnect or behave differently than others?

Even when hydrologically connected you have disconnection of solutes due to biology

Things I know about my data:

* Spatial variability is higher at low flow
* Concentration is higher at low flow (except maybe of electron acceptors?)
* Reducing conditions happen at low flow
* The system becomes both well mixed and permeable at high flow (high reaeration, usually a losing stream?)
* Influence of local hyporheic is higher at low flow.

The spatial variability is higher during periods of low flow. This is a signature both of connectedness and time spent in a habitat. Disconnection leads to a prominence of local controls. Most biogeochemical work happens at baseflow, or during low flows. Storms reset the system.

The upstream footprint of a gas is smaller than of an aqueous solute. These molecules cannot exit the system through atmospheric exchange.

**Spatial structure of stream biogeochemistry is constrained by geomorphology and hydrology**

**Introduction**

Streams have chemistry, it is important for organisms, water use, is shaped by biologeochemical processes.

Usually when we study it, we think about it as a well mixed system, with patterns on a continuum scale. Within stream heterogeneity has been found to be high. We have conceptual models to think about this: RCC, change along a river continuum, Patch dynamics (what paper is this?) River discontinuum. Longitudinal conceptual frameworks inherently suggest autocorrelation, while patch dynamics suggest local controls on water processing.

Most studies on biogeochemical heterogeneity focus on local controls rather than upstream influences.

A patch of stream water is chemically dependent on the internal processing, and the fluxes into and out of the system. We know that these can be longer or shorter.

A stream may shift between these to states depending on flow conditions. Hydrologic connectivity can break down during periods of low flow.

Ideas for paper reviews:

What are the goals of the paper? I'll start with the take home messages 1. Hypoxia is prevalent in Piedmont streams, more common than we may have previously believed due to sampling time and location biases. 2. It is spatially and temporally dynamic. patterns observed over the course of a day are similar in magnitude to those observed at the storm event and annual timescales. The controls on oxygen concentrations are hierarchical and complex, they act at multiple time and spatial scales. 3. To describe this variability, we need new ways of quantifying behavior that is biogeochemically relevant and that captures the different drivers at play. Okay, now the goals: to quantify hypoxia along a longitudinal continuum of a river. To link oxygen behavior to biogeochemical dynamics. To describe the geomorphic and hydrologic drivers of hypoxia.

What is a logical structure given those findings? 1. hypoxia in the piedmont has historically been present but only measured at low rates (WQP data) 2. hypoxia is observed at much higher rates in a single river in the Piedmont. 3. This indicates either a systematic sampling bias that misses low O2, or an increase in low DO over time, or both. The WQP data don't suggest an increase as far as I can tell (I could check this!). 4. The types of places that hypoxia occurs don't get sampled, but it is likely that they are common due to land use legacies (mill dams) and are increasing due to pressures of urbanization, climate change, disconnection with water table. This is a place where I can address that one review about how it doesn't make sense that I say NHC is a protected stream therefore we expect more of this to be found elsewhere, but then we also say that the WWTP is contributing the highest oxygen values that we see in the whole reach - this implies that dirtier streams would be more oxic. I say NO! the whole point I am trying to make here is that a lot of the low oxygen conditions we observe are related to low oxygen supply, not high oxygen demand (ie, geomorphic and hydrologic constraints vs. nutrient and DOC loading). This would suggest that structural modification of river networks is an important factor in altering water quality that we are systematically missing due to our bias toward regulating based on inputs to the system.

Where does this leave me? We need to have a better way of describing oxygen conditions and recognizing when they are biologically relevant (fish dead) vs. biogeochemically relevant (methane, mobilized contaminants). We also need to start looking in the places that we don't normally look and recognizing that anthropogenic hypoxia is not just a story of eutrophication but of land use and lanscape modification. It matters where our rivers are, how steep they are, where we put impoundments, how flashy they are, how well their groundwater is replenished, what the baseflow is. It's all there folks! It's complicated.